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BRIEF TEXT
OF
PHYSIOLOGY

CARL J. WIGGERS

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Phone 16.

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A
BRIEF TEXT
OF
PHYSIOLOGY
FOR
Dental, Pre-Medical, and College Students.

By CARL J. WIGGERS, M.D.
Department of Physiology, University of Michigan.

47 ILLUSTRATIONS

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PREFACE.

This text-book was originally written to supply the need of a concise and logical text for the use of dental students at the University of Michigan. In order to cover the subject of general physiology in the time allotted, the larger books, though excellently written and arranged, proved too voluminous and the existing smaller volumes failed to meet the requirements, either because the material incorporated seemed unwisely chosen, or because the mode of presentation did not render the facts readily assimilible. The choice of material and the sequence of presentation used in this work are those that past experience has shown best suited to the demands of dental students. Only subjects of greatest general interest have been included and discussions of debatable questions have of necessity been largely supplanted by statements of that side which, to the author, seemed to have the preponderance of evidence. The text has been illustrated by diagrams designed, as a rule, not for their anatomic accuracy but as graphical expressions of physiological facts to elucidate the text.

It is not the aim of this little volume to replace the larger text-books of physiology among medical students, but rather to antedate them. It is hoped that it may be accorded some favor by those teachers of medical physiology who take up the detailed study of body functions in connection with laboratory experiments but precede this by an introductory view of the whole subject.

The tabular summaries following each chapter should prove useful to medical and dental students, who, after a lapse of time, desire to review the subject preparatory to state board or hospital examinations. The subject-matter, with the exception of the chapter on the central

nervous system, which can be abridg
adapted to scientific courses in college
training courses for nurses, etc., whe
physics have formed a part of the cou
mented by the instructor. No pretense
ing this a text-book of anatomy as well
Enough anatomical descriptions have
however, to permit students in such
a general idea of the organs and tissue
they are studying.

It is fitting to acknowledge the ai
tributed to this work. The many perti
gained through an association with Pr
during the development of this course
to the worth this book possesses. Ma
of help rendered in preparing the man
been accepted with gratitude from Mrs

T

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SECTION I.

GENERAL INTRODUCTORY PHYSIOLOGY.

General Physiology concerns itself with the manifestations of life or the functions of living matter. Until comparatively recent times life was attributed to the existence of some mysterious vital force or principle, which, having flitted away, left the mass it inhabited a dead structure. As a result of physical and chemical studies and their application to living matter, however, scientists have come to regard life processes entirely as transformations of energy.

The energy of the universe can neither be created nor destroyed but may be changed from one form to another by means of machines. So, the energy of a waterfall may, by means of a dynamo, be transformed into electricity or the potential energy of coal may be changed by an engine into the kinetic energy which moves a train. Similarly, modern science regards our bodies as machines which change the potential energy of food into the energy which causes our muscles to move, our glands to secrete, our brains to think, etc. The processes concerned in the liberation of these forms of energy are termed the "**functions of living matter**" and serve to distinguish it from lifeless matter.

This transformation of energy in the body is intimately associated with chemical processes which are continually going on. In its ultimate analysis, living matter resolves itself into chemical compounds of the organic and inorganic groups. Every simplification of more complex bodies, or synthesis of simple bodies into the more complex, means a transformation of energy. Consequently, it is of fundamental importance to understand the chemical composition of the body and the chemical processes taking place within it, a study designated as **Physiological Chemistry.**

The various molecules of chemical substances group themselves into morphologically distinct units called cells, although many are contained in the connective tissues and fluids surrounding the cel assume many shapes and differ in their detail. It is the province of **Histology** these, while the grosser structures made called organs are studied in **Anatomy.** (structure have arisen as a result of ad: vious changes in function, so that di structure of cells and tissues finally goe with difference in function. Hence, it is only to delve into physical and chemical (which life processes are actuated but als the specific duties of the different cells, nated as "**Cellular Physiology.**"

It is evident that a study of the functi can only be made on living tissues and, as involve extensive operations, it is neces a large number of facts from observation mals and then to apply them with reser to the human body. A study of this "**Animal Physiology.**" There are, howev tions which may be studied by appropria unoperated human beings and some dat by surgeons during the course of opera speaking, the term "**Human Physiology**" ited to knowledge thus acquired.

CHAPTER I.

THE CHEMICAL CONSTITUENTS OF LIVING MATTER.

Both inorganic and organic chemical compounds enter into the composition of living matter. Among the former may be mentioned water and the salts formed by the combination of sodium, potassium, magnesium and iron with chlorides, carbonates, sulphates, phosphates, etc. The organic constituents are divisible into three main groups, **Carbohydrates, Fats** and **Proteins.**

CARBOHYDRATES.

Carbohydrates are organic substances composed of the elements, Carbon, Oxygen and Hydrogen. They are classified in three main groups according to their chemical complexity, and in further sub-groups according to the chemical reactions, as indicated below.

A. **Polysaccharides** [general formula $(C_6H_{10}O_5)n$] non-crystalline substances:

a) **Cellulose**—Insoluble in water, bursts in hot water, is stained yellow with iodine.

b) **Starch**—Soluble in water, reacts blue with iodine.

c) **Dextrins**—Soluble in water, give a red color with iodine (Erythrodextrin) or no reaction (Achroödextrin).

B. **Disaccharides** [general formula $C_{12}H_{22}O_{11}$] crystalline substances, readily soluble in water.

a) **Sucrose**—Gives no reaction with iodine, does not reduce copper salts in alkaline solution.

b) **Maltose**—Gives no reaction to iodine, reduces copper salts in alkaline solution.

c) **Lactose**—Gives no reaction to iodine, reduces copper salts in alkaline solution.

C. **Monoscharides** [general formu talline substances, soluble in water salts in alkaline solution.

a) **Dextrose.**
b) **Levulose.**
c) **Galactose.**

THE POLYSACCHARIDES:—S tributed in the vegetable kingdom bu mal tissue. It exists in various sha ules, each granule being surrounded As cellulose is not soluble in cold wa in this wall cannot go into solution ruptured, hence it is often said that in cold water.

Dextrins are formed as intermedi tion. There are two forms distin other by the fact that one reacts t color (**Erythrodextrin**) and the othe (**Achroödextrin**). Dextrins are als tissues where they are called **Glycoge**

All polysaccharides may, by hydr into disaccharides. The reaction m the formula

$$2(C_6H_{10}O_5)+n(H_2O)=n(C_{12}$$

THE DISACCHARIDES:—Sucro rived from the sugar cane and beet of the sweet flavor of many fruits a crose is the only disaccharide that d **ling's solution.** This well known copper sulphate, potassium hydroxi sodium tartrate (Rochelle Salt). T boiling the Fehling's solution and t quantity of the substance to be teste copper salts is indicated by the prese tate of cuprous oxide. **Maltose** der its presence in fermenting barley but tive stage of carbohydrates. **Lactos** Both of these carbohydrates reduce All disaccharides are changed by h saccharides, thus

$$C_{12}H_{22}O_{11} + H_2O = 2C_6$$

THE MONOSACCHARIDES:—The monosaccharides are all end products of digestion or hydrolysis. **Maltose,** by hydrolysis, yields two molecules of dextrose. **Sucrose** yields a molecule of dextrose and one of levulose. **Lactose** yields a molecule of dextrose and one of galactose. All monosaccharides are of the same chemical structure and give the same reactions, but they differ in their behavior to polarized light.

FATS.

Fats are oily or waxy substances which are insoluble in water but soluble in alcohol, ether. Chemically, they are organic compounds of carbon, hydrogen and oxygen.

The fats entering especially into the composition of animal tissues are **Palmitin, Stearin** and **Olein.** Olein is an oil at ordinary temperature, while palmatin and stearin are wax-like substances. A mixture of the three gives fats possessing a soft consistency, as lard, butter, etc.

By hydrolysis, fats are split into their constituent portions, fatty acids and glycerine. Thus,

$$C_3H_5(C_{15}H_{31}COO)_3+{}_3H_2O=C_3H_5(OH)_5+{}_3C_{15}H_{31}COOH.$$

palmitin water glycerine palmitic acid

Similarly, stearin and olein are broken up into stearic and oleic acid plus glycerine.

Saponification of Fats:—When the hydrogen of a fatty acid is replaced by the base of an alkali, a soap is formed or, using another expression, fats are said to be saponified. Thus,

$$C_{15}H_{31}COOH+KOH=C_{15}H_{31}COOK+H_2O.$$

palmitic acid potassium soap

Soaps are readily soluble in water and serve as emulsifying agents for fat globules.

Emulsification:—If a mixture of oil and water is allowed to stand the oil will rise to the top. If, however, a small quantity of soap or other emulsifying agent is added to the mixture, the fat after being shaken will remain in suspension and give a milky appearance to the fluid. This is called an **Emulsion.** Each fat droplet is surrounded by a very delicate film, such as may be seen to enclose the air of a soap-bubble.

LIPOIDS.

Lecithin and Cholestrin:—Lecithin : two substances resembling fats in their teristics but differing in their chemical are therefore called Lipoids. Lecithi stance in which the fatty acid radical is ine as in ordinary fats, but in which the is replaced by an ester-like radical of phoric acid. Cholestrin, which crystall bic form, is a monatomic alcohol.

PROTEINS.

Proteins are complex, organic substar cular weight. Serum globulin, for exan timated to have a molecular weight of are composed of the elements carbon, h and nitrogen. Some also contain pho and iron. These elements are arrang molecule as definite chemical radicals w off leaving the molecule simplified. T tion of the chemical molecule is compo Emil Fischer, of a large number of a have been designated by him as its (Bausteine). All of these acids have a structurally represented as

$$NH_2—C—COOH$$

The number of these radicals and thei the molecule determine the character of form, just as the arrangement of bric configuration of the structure of which There is apparently but one requirement number and arrangement of the amino- constitute a protein molecule, that is, t molecule must contain the two mono-a **sin** and **tryptophane.**

Classification:—The proteins may be following groups and sub-groups:

I. SIMPLE PROTEINS.

A. **Globulins**—Serum-globulin, fibrin ulin, myosin.

B. **Albumins**—Egg-albumin, serum-albumin, lact-albumin, myogen.

II. DERIVED PROTEINS.

A. **Proteoses.**
Peptones.
Polypeptids.

III. COMPOUND PROTEINS.

A. **Chromoproteins**—e. g. hemoglobin.
B. **Glucoproteins**—e. g. mucin.
C. **Nucleoproteins**—e. g. casein, proteins of the nuclei.

Simple Proteins:—Simple proteins enter largely into the composition of the body cells and body fluids. Albumins are soluble in distilled water while globulins are not. They are readily brought into solution, however, by the addition of any neutral salt. All simple proteins are coagulated by heat and precipitated by a large number of chemical reagents. Among these may be mentioned the mineral acids, alcohol, salts of heavy metals (copper sulphate, lead subacetate, potassium ferrocyanide), and organic acids (as tannic, picric). Proteins also give color tests with certain chemical agents, among which the following are most commonly employed.

1. **The Biuret Reaction.** A small amount of protein in solution is rendered alkaline with KOH and heated. Two drops of an exceedingly dilute copper sulphate solution are then added. A pinkish purple tinge is given to the solution.

2. **Millon's Reaction.** Millon's reagent consists of mercuric and mercurous nitrate in nitric acid. The test is carried out by adding a few cc. of this reagent to the solution of protein. A white precipitate forms. This is heated, causing the precipitate first to cling together in a mass, and, second, to change its color to a bright red. The solution may also turn red.

3. **The Xanthoproteic Reaction.** A few drops of nitric acid are added to a protein solution, causing a precipitate. Heating changes the color to a bright yellow. The addition of sufficient ammonia water to render the contents alkaline causes a change of color to orange.

When treated with dilute acids and heat simple proteins undergo hydrolysis and so are split into simpler molecules containing fewer amino groups, called the derived proteins.

Derived Proteins:—Proteoses are s
water, are precipitated by mineral aci
but are not coagulated by heat. Pept
soluble in distilled water, are not preci
acids nor coagulated by heat. They
action in the cold. Polypeptids are con
or more amino radicals. They are cry
but give the biuret reaction which wa
fication as proteins.

Compound Proteins:—When a no
attached to the simple protein molecul
tein results. Thus, chromoproteins con
group, glucoproteins a carbohydrate r
proteins a nucleic acid radical. Nuclei
ized by its high phosphorus content an
offered to digestion.

ALBUMINOIDS.

The term albuminoids is given to a c
derived from connective tissue, cartila
are composed of amino-acids radicals
lack either or both the tryptophane an
Gelatin, which may be cited as an exa
Gelatin is soluble in hot water but o
jelly.

CHAPTER II.

PROTOPLASM.

Protoplasm, of which all living cells are composed, may be most simply studied in a microscopic form of animal life, the ameba. This animalcule, composed of a single cell, is usually found in the slime of sluggish pools. Viewed under a magnification of 300 diameters, its protoplasm appears as a semi-solid, colorless, translucent and often granular mass of irregular shape. Closer inspection reveals a clear outer zone, the ectosarc, differentiated from the more granular inner portion, the endosarc. Within this there is usually visible a small, round or oval denser area, the nucleus. Within this, a still denser spot, the nucleolus, can be made out by the use of stains.

Histologically, the protoplasm of cells reveals, after fixation and proper staining, a spongioplastic network, in the meshes of which a more fluid portion, the paraplasm, is stored. The nucleus consists of a somewhat coarser network spoken of as the chromatin network which is surrounded by a more or less definite nuclear membrane.

A chemical analysis of protoplasm is impossible, for, as soon as it is treated with chemical reagents, it is killed, and is, therefore, no longer protoplasm. Dead protoplasm, if we may speak of it as such, has been found to contain from 72 to 75% of water and 18 to 20% of proteins, the balance being made up of inorganic salt ions. Among the latter may be mentioned the chlorides, sulphates and phosphates of Na, K, Ca, Mg, etc. Living protoplasm has no constant composition but is continually changing its chemical makeup.

Physically, protoplasm is colloidal in nature, due to the proteins it contains. Colloids are structureless substances which do not easily pass through animal membranes. Gelatin is a good example. Colloids may exist in various states. If a piece of gelatin is allowed to imbibe a small quantity of water it becomes of a gelatin-ous consistency. Such a colloid is ca lowed to imbibe still more water it goe is then called a **Sol.** In either case its It is structureless and translucent and the same chemical reactions. If tre chemical reagents, it may be precipitat an opaque white mass. It is now no l this condition it is apparently homogen ined microscopically, it is found to consi comb network not unlke that seen in sta

The results of these and other similar led many physiologists to the belief t plasm is a homogenous, structureless m network seen by histologists being an a from the precipitation of its colloid, cau ening and staining processes it has be On this basis the nucleus is regarded as within a colloid, a state of existence quit physical point of view. To what exten network may be regarded as existing o specimens, is, at present, undecided; b due to precipitation, there is no doubt th place within it, as is evidenced during n sion.

SUMMARY—THE NATURE OF PR

1. **General Appearance as revealed in the l**
   Colorless, transparent, granular mass—D ectosarc and endosarc—Contains nucleu

2. **Histological Picture of Stained Protopl**
   No distinct cell wall—Paraplasm, the flui plasm, the network of granules—Centr containing chromatin network.

3. **Chemical Composition—**
   Proteins—Salts as Na,K,Ca,Mg, in the phates, chlorides, sulphates, etc.—Water.

4. **Physical Nature—**
   Colloidal substance—Capable of changing sol-like to gel-like condition without chan —Precipitants cause formation of transcule a change in its nature—The nucleus is a a colloid.

THE FUNCTIONS OF PROTOPLASM.

An ameba, watched under suitable conditions, may be seen to change its shape by a small amount of protoplasm flowing into arms-like projections from the cell itself. These projections are spoken of as pseudopodia and are the animal's means of locomotion. If, during the course of the animal's wanderings, it meets any irritating substance, the pseudopod is withdrawn and the ameba assumes a different shape. This property of altering its shape is called **Contractility.** It should be borne in mind that no diminution in the bulk of the ameba occurs and thus the process differs from the contraction of iron or other metals that we learn about in physics. The substance which started this reaction in the ameba is termed an **Irritant** or **Stimulus,** and the property which enabled it to react is called **Irritability.** An irritant which excites the cell from without is designated an external irritant; one that stimulates it from within or is generated within the cell is called an internal irritant. A cell which generates its own irritants is said to possess **Automatism** or **Spontaneity.** This is manifested when an ameba moves of its own accord.

An irritant applied to one small portion of the ameba may cause a general contraction. In this case the irritant sets up a process called an **Impulse,** which is transmitted across the cell to all its parts. This property of protoplasm by which it transmits impulses is spoken of as **Conductivity.**

An ameba will not withdraw from all articles in its path, but will surround food particles by allowing its pseudopodia to engulf them. If an ingested particle is further watched within the cell, it will be seen to undergo changes in size and color and, finally, most of it will disappear. It has been digested. The portion which cannot be digested is thrown off by the ameba flowing away from it, as it were. Thus we have the processes of **Prehension, Ingestion, Digestion** and **Egestion** carried on by a single cell.

Closer investigation of the digestive process has shown that the ingested particle is attacked by a chemical substance generated or **secreted** by the cell and called an **Enzyme** or **Ferment.** The enzyme secreted by the ameba

is capable, probably, of splitting up only p
therefore designated as a **Proteolytic ferm**
ment changes the solid particle to a simple
a liquid state, the chief objects of digesti
rendered liquid is able to reach all parts
Absorption and is utilized to again build
plasm of the cell, a process spoken of as **A**

After such repeated additions to its pr
ameba must necessarily increase in bu
Growth, which is one of the chief characteri
cells, occurs by additions from the inside,
with the growth of an inanimate object suc
which is added to by the accretion of outsid
constant tendency of the cell to grow wou
a great increase in bulk were it not for the
tendency to break down. Whenever an am
secretes an enzyme a certain amount of
pended and a corresponding amount of its ce
broken down. As a result, the ameba loses
energy liberated results from the combusti
plasm, just as an engine liberates energy in
of fuel. **Combustion** means oxidation.
burnt protoplasm has no available energy
excreted. The term **Excretion** is limited to
ing of substances which have once been a pa
protoplasm, and cannot be applied to the
substances which have never been a part
Indigestable substances thrown off by a
passed through the alimentary tract of a
can not be regarded as excretions.

A burning fire needs not only fuel but o
same holds true for the cell in which a slo
goes on. It is the function of **Respiration** t
cell with oxygen, and to free it from car
Respiration is a diffusion process. If two
or in solution, are separated by a permeabl
each tends to pass to the other side until th
of each is the same on both sides. This pro
between the ameba and the surrounding wat
passes in from the water and CO_2 out to the

As a result of combustion, no matter how
is liberated. In many animals, the ameba a
the heat generated is rapidly given off and t

ture of the animal is practically maintained at that of the surrounding medium. In other words, the heat generated is counterbalanced by the heat dissipated. This occurs in all cold-blooded animals. In warm-blooded animals, however, the heat generated is kept in by a regulating device, and such animals consequently maintain a temperature independent of the surrounding medium.

A cell thrives only when the substances taken in at least equal in weight those given off. If the weight of food plus the oxygen equals that of the excreta plus the CO_2, the cell is said to be in **Physiological Equilibrium.** If it is less, the cell dwindles away; if it is more, it grows. The changes in the constitution of the cell are spoken of as **Metabolism.** The building-up processes are called **Anabolism,** the tearing-down processes, **Catabolism.** If anabolism exceeds catabolism the cell grows, and, as a result of excessive growth, it finally divides and forms another cell. Thus, we have the functions of **Growth** and **Reproduction,** which are the most characteristic properties of living tissue.

SUMMARY.—THE FUNCTIONS OF PROTOPLASM.

1. **Contractility**—The ability to change shape without a change in bulk.
2. **Irritability**—The ability to respond to an irritant or stimulus.
3. **Conductivity**—The ability to transmit a state of excitation from one part of the cell to another.
4. **Digestion**—The change of food from a more complex to a simpler chemical state, or from a solid to a liquid form. It involves:
    a) Prehension and Ingestion.
    b) Secretion and the liberation of substances (ferments or enzymes) to act on foods.
5. **Absorption**—The distribution of digested material.
6. **Assimilation**—The construction of digested material into a part of cell protoplasm.
7. **Respiration**—The interchange of O and CO_2 for combustion purposes.
8. **Growth**—An increase in bulk of protoplasm; anabolism exceeding catabolism.
9. **Reproduction**—The division of one mass of protoplasm into two or several masses.
10. **Excretion**—The elimination of products of cell break-down.

THE PHYSIOLOGICAL SPECIA PROTOPLASM.

Under adverse conditions, the ame
in an active state, but, having stored
ment as possible, it draws itself into a
surrounds itself with a thick cell w
remain for a long time, showing no
life. The properties that once charac
dormant. From this quiescent condit
quently develop into an active ameba
its investing cell wall.

The human being has its origin in
Ovum, which is not unlike an encys
round, nucleated and made up of pr
rich in stored material, and, therefore
yolk. It is surrounded by a speciali
posed of two layers. The thinner one
Vitelline Membrane, the outer one,
appear to be radial striations, the **Zona**
I).

The ova develop and mature in the o
situated bilaterally in the female pelvi
an oyster in size and appearance. W
ture from the surface of the ovaries and
by way of the Fallopian Tubes, whos
close proximity to the ovaries. If
spermatozoon in the Fallopian tubes,
a stimulus by the act, which awakens
tions, and it assumes all the propertie
living cells. It now attaches itself to t
surface of the uterus and by a digestio
into the mucosa. At first it lives on it
but, as soon as it comes more intimate
the vascular spaces of the uterus, solubl
pass by diffusion from the maternal ci
ovum, while the waste products and C
a result of this, the ovum grows ra
rapidly divides by karyokinesis, for th
other books must be consulted.

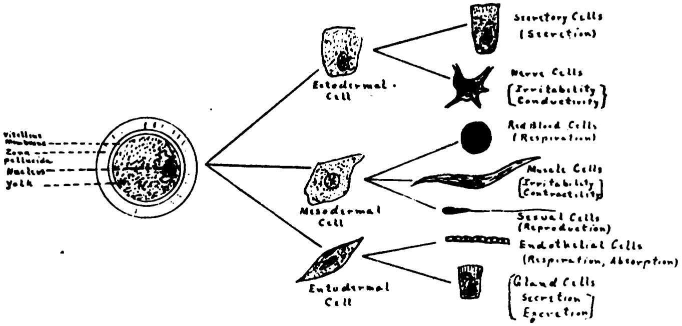
Vitelline Membrane
Zona pellucida
Nucleus
Yolk
Ectodermal Cell
Mesodermal Cell
Entodermal Cell
Secretory Cells (Secretion)
Nerve Cells [Irritability Conductivity]
Red Blood Cells (Respiration)
Muscle Cells [Irritability Contractility]
Sexual Cells (Reproduction)
Endothelial Cells (Respiration, Absorption)
Gland Cells Secretion Excretion

Figure I. Scheme, showing Structure of Ovum and the Specialization in the Functions of Cells to which it gives rise.

The fertilized ovum, like an encysted ameba, potentially possesses all the functions of protoplasm. As it divides and subdivides, however, not all the resulting cells assume to the same degree all, of these functions. A **Physiological Division of Labor** occurs among the cells. Just as, when a community grows, some of the inhabitants become artisans, others traders, and still others follow a professional career; so one group of cells specializes in the functions of irritability and conductivity and becomes nerve cells and fibers, other groups in contractility and irritability and become muscle cells, while still other cells specialize in secretion, absorption, respiration and reproduction. (Figure I.) As a result of this specialization, each group of cells has its own function to perform, but it should not be forgotten that each retains to some degree, all the latent properties of the ovum whence it came. So muscle cells not only contract, but to a lesser extent secrete, absorb and undergo processes of nutrition, respiration and reproduction. The power of a tissue to reproduce is limited to the production of its own kind. Thus, brain cells reproduce only brain cells (i. e., only before birth), liver cells reproduce only liver cells, while the specialized sexual cells reproduce an entire new individual. Meltzer phrases this very well in the statement, "The same source which provides the organism with a mechanism for the reproduction of the whole body, provides its parts with a mechanism for the regeneration of these parts."

SECTION II.

THE FUNCTION OF SPECIALIZE TISSUES.

CHAPTER III.

THE WHITE BLOOD CELLS (U TIATED FUNCTION.

The white blood corpuscles are cells w
approach the ameba in possessing ma
tions, without specializing particularly
tion. Like that of the ameba, their pr
self-preservation, and, in the effort to su
they also become of service to other ce

Varieties.—The white blood cells ma
Lymphocytes and **Leucocytes.** The
clear protoplasm and rarely show ame
the latter have a granular protopla
ameboid movements. Lymphocytes
lymph glands and spleen. Leucocytes a
red bone marrow. Lymphocytes may f
into two sub-groups, the large and the
lymphocytes form about 1% of the t
corpuscles and are distinguished from t
only by their size but also by their
eccentrically placed and pale, while t
ones are centrally located within the ce
small lymphocytes form 26% of the
The leucocytes are divided from the a
nuclei into **Transitional, Polymo**
Polynuclear Leucocytes. The first
horse-shoe shaped nucleus and compri
the total number of white cells. Th
characterized by a much lobulated n
such. They form as much as 70% of
of white cells.

The white blood cell possesses many
of the ameba. Independent motion

referred to, but this is little utilized in helping the cells to move through the blood stream, as they are largely pushed along by the current. It is useful, however, in an important process known as **Diapedesis.** Within the capillary blood vessels where only a single layer of endothelial cells separates the blood from the tissue spaces, the leucocytes are known to squeeze between these cells and thus escape from the blood stream. This occurs by the protrusion of a pseudopod of the leucocyte between these endothelial cells, and then, by successive steps, the whole leucocyte slips through. By virtue of the ameboid movement, aided by the lymph flowing through the tissue spaces, the leucocytes wander away from the blood-vessels and are therefore designated as "wandering cells." Normally the majority of the leucocytes in the body are not within the blood stream but are scattered through the lymphoid tissue and lymph spaces. At certain times, for example, after a meal, after exercise, or as a result of a cold bath, they wander back to the blood stream by reverse diapedesis, so that their normal number in the blood (6000 to 8000 per cubic millimeter) is increased. This is spoken of as **Physiological Leucocytosis.** As a result of poisons or toxins introduced into the blood, as happens in many infectious diseases, leucocytes not only enter the blood stream from all places where they are found in the body, but the total number in the body is increased, through a production of new leucocytes. Such an increase gives rise to what is called **Pathological Leucocytosis.**

The nutrition of the white blood cell is largely maintained by the inward diffusion of soluble substances of the blood and in part only, by the ingestion of solid particles such as fat globules, fibrin or even bacteria, a process called **Phagocytosis.**

Recent studies have shown that the ingestion of bacteria is not a haphazard function of the leucocytes, but does not occur unless the bacteria have been previously prepared by chemical substances called **Opsonins.** The presence of bacteria and their products probably stimulates the various body cells to elaborate and throw into the blood these opsonins which, later, by chemically uniting with the bacteria, render them suitable for destruction by the leucocytes.

Once ingested, these solid substanc
they were by the ameba. This cell, h
remembered, could digest only protei
sesses only a proteolytic ferment. Th
fats also, as they possess a **Lipolytic**
The fact that they can digest bacteri
ascribe a bacteriolytic ferment to the
is not improbable that the digestion
to the proteolytic and lipolytic ferme
further extremely probable that the
another substance into the blood whic
ing it.

Investigations as to the action of
Opie, have shown that certain conditi
for their action. Thus, the proteolyti
by the large mononuclear lymphocyte
an alkaline medium, while the pr
secreted by the polynuclear leucocyte
acid medium. It thus becomes appare
teolytic enzymes act alike or are iden

The leucocytes were previously sai
in their protoplasm. Histologically, the
their behavior to stains, **Acidophil, B**
trophil. Physiologically, they are as
secreting process of the cells. Enzy
ready formed in cells, but as **Pro-enzym**
granules, which change to the activ
needed. In the leucocyte they probab
various ferments before discussed.

It will be seen, then, that the white
life to a large extent for their own i
dentally, they perform various roles in t
destroy bacteria and other solid mate
removed, would prove injurious to the
2. They aid in the absorption of fat f
3. They aid in the coagulation of the
help to maintain the composition of t
extracellular excretions and their own

SUMMARY.—THE WHITE BLOOD CORPUSCLES.

I. Varieties—

A. Lymphocytes—clear protoplasm, round nucleus, rarely possessing ameboid movement—formed in the spleen and lymph glands.

Subgroups—1. Small (26% of total white cells). 2. Large (1% of total white cells).

B. Leucocytes—granular protoplasm, marked ameboid movements, formed in the red bone marrow.

Subgroups—1. Transitional, horse-shoe shaped nucleus, forms 3% of white blood cells. 2. Polynuclear. 3. Polymorphonuclear. The latter two comprise 70% of total white blood cells.

II. Specialized Functions—

1. Contractility and Irritability responsible for:
   - a) Diapedesis, the passing of leucocytes through endothelium of blood vessels.
   - b) Leucocytosis; their return to the blood.
2. Digestion responsible for Phagocytosis, which includes:
   - a) Sensitizing of bacteria by opsonins.
   - b) Their mechanical inclusion.
   - c) Secretion of enzymes, proteolytic, lipolytic, bacteriolytic.
   - d) Digestion of ingested particles.

CHAPTER IV.

THE RED BLOOD CE

(Respiratory Functio

The red blood cells or erythrocyte
in the red bone marrow. Here they
less, nucleated cells, which undergo r
Finally the nuclei disappear either by
cell or by dissolution, and the non-n
discs, which have acquired a red colo
The red blood cells are much more
white cells, each cubic millimeter cont
000. It is difficult to give any definite
ber of corpuscles, however, as so ma
cause a variation. The number of red
tively greater in infants than in adults
numerous in the male than in the f
increase the number, while meals se
High altitude is a well known factor
crease in their number. Whether thi
pensatory increase in the number of r
the deficiency of oxygen, or merely
of the blood by a removal of water, re
problem.

The life of a red blood cell is ver
undergoes disintegration within the
comes of the products of disintegratio
cussed. (Page 99.)

Each red blood cell is composed o
the corpuscle shape and elasticity,
coloring matter, water, salts; and
Lecithin and **Cholestrin** are present.
in the corpuscle in an amorphous con
tion. Under the influence of many
and toxic agents the red cells are bro
hemolysis, in which case the hemogl

solved in the plasma. It can also readily be extracted with ether, alcohol or water. The presence of hemoglobin, even in minutely small quantities, can be detected in any mixture (urine, feces, stomach contents, suspicious stains, etc.), by the application of **Weber's Test.** In principle, this test consists in first changing the hemoglobin to hematin by the addition of glacial acetic acid, and then extracting with ether and testing this ethereal extract with a little powdered guiac and some oxidizing agent, as hydrogen peroxide, which develops a blue color. In **Rossel's Test,** aloin is substituted for the guiac and a red coloration results.

The chief function of the red blood cells is that of respiration. This consists in carrying the oxygen from the lungs to the tissues, and the CO_2 in the reverse direction. To make this process understood, it should be recalled that, chemically, hemoglobin is a compound protein consisting of **Globin** and **Hematin,** an iron containing substance. When blood passes through the lungs, oxygen combines loosely with the hematin portion of the hemoglobin, converting it into **Oxyhemoglobin.** This has a bright scarlet color. After being transferred to the capillary areas of the body, the oxygen is given off, and Co_2 combines with the globin portion of the hemoglobin. This compound is spoken of as **Reduced Hemoglobin** and has a purplish-red color. Certain other gases which may be inhaled also combine with hemoglobin. Carbon monoxide (CO), a constituent of coal-gas, combines firmly with the hematin and thus prevents it from linking with oxygen, therefore the compound **CO-Hemoglobin** is poisonous to the body, causing asphyxiation of the tissues through lack of oxygen. CO-hemoglobin has a bright cherry red color.

H_2S is another gas forming a combination with hemoglobin and changing it to a greenish color. Certain agents, as nitrites, for example, are also capable of changing oxyhemoglobin into a stable compound of oxygen and hemoglobin **Methemoglobin.** A chocolate brown color accompanies the formation of this compound.

SUMMARY—THE RED BLOC

1. **Origin—**

Colorless cells of the red bone m
hemoglobin acquired.

2. **Number—**

Average figure 5,000,000—variation
sex, altitude, etc.

3. **Function—**

Respiration—Oxygen carried to the
from the tissues.

4. **Composition—**

Protoplasmic stroma—Hemoglobin
dition—Salts—Water—Lecithin a

5. **Varieties of Hemoglobin—**

a) Oxyhemoglobin—scarlet red
to hematin portion.

b) Reduced hemoglobin—Purp
linked to globin portion.

c) CO hemoglobin—cherry red
hematin in firm combinatic

d) H_2S Hemoglobin—Green co

e) Methemoglobin—Brown chc
held in firm combination.

CHAPTER V.

THE PHYSIOLOGICAL PURPOSE OF TISSUES. (THE BLOOD.)

Cells can functionate best for a common or similar end when they are aggregated and bound together by some connecting medium. This is usually accomplished by a more or less architectural interweaving of certain fibrils and fibers, and the network formed by these is spoken of collectively as **Connective Tissue.** In it the cells are so arranged that they occupy an orderlv relation to each other, and are, in addition, supplied with a mechanism which enables them to work together. A phvsiological study of a **Tissue,** as such an aggregation of cells is called, involves then, not only a studv of the active cells and their source of nourishment, but also a consideration of the connecting framework, and the mechanism controlling cell functions.

The blood represents a tissue, in which the connection between its cells consists of a liquid portion, the **Plasma.** The plasma contains in solution at least three varieties of proteins, two of which, serum-globulin and serum-albumin, serve as nitrogen food for cells. The other, fibrinogen, aids in the coagulation of the blood. Besides these, certain other substances may be extracted by chemical reagents. Among these are sugars and fats, which are energy-giving foods for cells. The plasma also contains excretory products, of which urea may be mentioned as an example. In addition, small but essential quantities of sodium, potassium, magnesium, calcium and iron in the form of chlorides, carbonates, phosphates and sulphates are present, which serve to maintain the osmotic pressure relations. Calcium, in addition, aids, as we shall see, in the coagulation of the blood.

Such is the menstrum in which each blood cell lives, as was before pointed out, its own life. The question now arises, "Is any means present for co-ordinating the various cells of the blood for a useful end?" It has already been seen that, after the introduction of foreign

material into the blood, a general wand
cytes to the blood stream occurred (L
that this was a concerted movement
seem, had some general regulation.

It has been known for some time
stances in solution attract, while otl
forms of life, a phenomenon spoken c
It has recently been suggested that v
introduced into the body they secrete
stance, or the products of digestion s
stimulus, which, acting like a messeng
stimulates all the leucocytes througho
brings them into the circulation and
danger. To such "chemical messeng
given the name **Hormones.**

It is thus seen that the blood plasm
as a connecting medium and a mea
nourishment to the corpuscles, but th
a chemical regulative mechanism for t

The connecting medium of the blo
liquid. Under certain conditions a fibr
appear in which the blood cells are ca
in clotting of the blood, which is on
cinating properties. The process of c
gradual one and takes place as follow

1. The liquid portion becomes of
consistency.

2. On standing, this becomes firm
if contained in a vessel, the receptacl
without spilling the contents, the **Clo**

3. The clot next shrinks and sque
colored liquid, the **Serum.**

What causes the separation of thi
during coagulation? Many hypothes
ordinary complexity, have been sugge
phenomenon. The latest researches,
indicate that whenever a stimulus ar
tion, injury or irritation of the vessel
drawing of blood, a substance, **Proth**
plasma. Which cells form or secrete
known, but probably the white blood

tain other small amorphous bodies, the blood-platelets, have this function. Prothrombin, once formed, quickly combines with calcium to form **Thrombin.**

Prothrombin+Calcium=Thrombin.

The thrombin then precipitates fibrinogen and changes it to fibrin (a solid) which forms the clot.

Thrombin+Fibrinogen=Fibrin.

Within the meshes of the fibrin red and white blood cells are caught and the former give the clot its red color. The serum which is squeezed out differs from the plasma in that it contains no fibrinogen or red and white blood corpuscles. It is a dead substance.

If blood be vigorously beaten with a rod soon after collection, the fibrin will cling to the rod and the fluid remaining, unlike serum, will have a red color. This fluid is **Defibrinated Blood,** and resembles normal blood in composition, except that it contains no fibrinogen. Coagulation may be prevented in several ways. One is to receive the blood into a receptacle containing sodium oxalate solution. The calcium is then precipitated, and the formation of thrombin prevented.

SUMMARY.

I. PHYSIOLOGICAL REQUIREMENTS OF A TISSUE.

1. An aggregate of cells with similar or the same functions.
2. A connection of fibers or fluid (connective tissue).
3. A supply of nourishment.
4. A regulating mechanism for the cells (a) nervous, (b) chemical.

II. COMPOSITION OF PLASMA AND FUNCTION OF EACH CONSTITUENT.

Serum-albumen—Nitrogen food.
Proteins Serum-globulin— " "
Fibrinogen......Aids in coagulation.
Dextrose—Energy-yielding food.
Fats Energy-yielding foods.
Urea
Lecithin and Cholestrin
Salts of Na,K,Mg,Fe To maintain osmotic pressure.
Po_3,SO_4,CO_3,O

Ca...................aids coagulation.
Water..............connecting menstrum.
Internal secretions.
Hormones........chemical regulation.
Opsonins.

III. COAGULATION OF BLO

Leucocyltes and blood plates shed Prothro
Prothormbin+Ca=Thrombin.
Thrombin+Fibrinogen=Fibrin.
Red blood cells are caught in meshes.

IV. MODIFIED BLOOD

Serum=Blood Plasma—Fibrinogen.
Defibrinated Blood=Cerum+Red Blood C
Oxalated Plasma=Blood Plasma—Calcium

CHAPTER VI.

SECRETING CELLS AND GLANDULAR TISSUE.

(Secretion).

Secretory cells may, from their appearance and the nature of their secretions, be classified in two groups, viz. **Serous** and **Mucous Cells.**

If we look at a microscopical section of fresh serous cells taken from an animal whose glands have not recently been secreting, we will observe that the cells have a ground glass appearance due to the fact that they are filled with many small granules. These are the pro-enzyme granules which later give rise to ferments. A section of fresh mucous gland, under the same conditions, shows many points of difference. The cells have well defined boundaries and do not possess the ground glass appearance because the granules are fewer and larger. These represent an early stage of mucin.

If serous cells which have been removed during activity are examined, the section will show that the outer border of the cells has cleared up and contains no granules. This causes the outlines to become distinct. Only after the cells have secreted very much do the granules entirely disappear and the cells grow smaller. It is questionable whether this stage ever occurs in the normal body activity. After secreting, granules gradually reappear in the protoplasm of the serous cell and it recovers.

In secreting mucous cells, the granules entirely disappear very early and evenly so that the whole cell becomes filled with a clear, transparent substance which is later given off. Many such cells after discharging their contents probably entirely disintegrate, while it is possible that some rebuild from the small nucleated portion that remains after the mucin is liberated.

It will be seen that great stress is laid on the appearance of fresh sections, and none on the pretty preparations obtainable by staining methods. The reason is that any chemical manipulation necessary to stain cells,

changes the protoplasm. The coagu
teins by fixing and hardening tissues
a process which is liable to give rise
granules, to change the relation of
to cause clumping or disappearance

The Nature of Secretions.—The p
by secretory cells are spoken of a
These differ markedly in their gene
Some secretions, as those discharged
thin and watery while others, as th
mucous cells, are thick, stringy and n
Secretions also vary markedly in t
position. In addition to water and in
in varying proportions form two of t
constituents, secretions contain othe
portant substances which, from their
may be placed in the following classes

1. **Enzymes or Ferments.** Enzy
substances readily soluble in water
are destroyed by a temperature exc
centigrade. They are catalytic agents
themselves undergo any change, but,
accelerate reactions already taking pl
rate. Examples of catalytic agents
with in every-day life. Many vola
gasoline, benzine, etc., have a constan
into flame. By bringing a wire of p
contact with them, however, the reac
so that a flame results. This princ
many patented "pocket lighters." Ag
oxide has a constant tendency to slow
By the presence of organic matter thi
diately accelerated so as to make th
visible as a foam.

Similarly, all complex organic subs
tendency to break up into simpler one
accelerate this reaction by catalysis.

Enzymes are further characterized
of their actions, i. e., each enzyme is
a certain kind of food as "a key fits i
more, some require the presence of a
of a base in order to act, as has been

2. **Hormones.**—This group of substances secreted by gland cells differs from ferments in that they are crystaline in nature, not destroyed by heat, and stimulate other cells or modify their functions. The "hormones" acting as messengers to the white blood cells and inducing leucocytosis have already been discussed and many others exist in the body.

3. **Substances** belonging to neither of these classes but of functional use. One of these substances has already been mentioned, viz., thrombin. The latest researches seem to show that this substance is not a ferment in the strictest sense, since it is not detroyed by heat and does not act by catalysis, but as a quantitative precipitant. In this class may also be placed the HCl of the stomach and the alkalies of the pancreas necessary for the action of the ferments and the emulsifying agents of the bile which facilitate fat digestion, etc.

4. **Excretory Substances.**—These embrace a class of substances which, are of no use either directly or by indirect action, to other cells, but which, if accumulated within the body, exert an injurious action on its cells.

GLANDS.

Secretory cells united into a group by connective tissue are designated a **Gland.** As the cells of a gland are thus firmly bound together and stationed on a basement membrane, it is necessary that nourishment and oxygen be carried to them, and that their excretions and CO_2 be carried away. This is accomplished by an intricate lymphatic system and the blood vessels, the arteries carrying building substances to the cells, and the veins taking broken-down substances away.

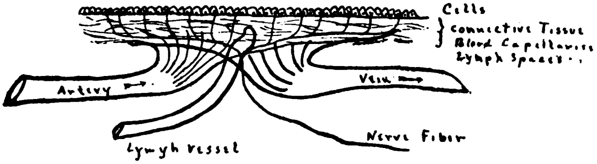

Figure II. The Constituents required in a functionating gland.

Gland cells are made to work fo
through the regulation of nerve fibers
rebranch, finally to terminate on the s
sum up, the elements necessary to mak
ing gland are: secreting cells arrang
membrane; connective tissue, holding
tions together; blood vessels, arteri
carrying oxygen and nourishment to
carrying CO_2 and waste products aw
and spaces aiding the vascular system
the secretion.

CLASSIFICATION OF GLAN
glands are classified according to the
tion which the secreting cells bear
tissue. The simplest type of a glan
the cells are arranged in a straight s
nective tissue and blood-vessels. Suc
be designated a **Simple Secreting Sur**
A.) The crypts of Lieberkuhn in the
an example of the next higher type of
ple Tubular Glands, which are form
tion of the simple secreting surface i
tissue. (Figure III, B.) If glands bu
necks so as to assume a flask-shape
ance, we speak of **Saccular or Alveola**
the sebaceous glands are illustrations
Further invaginations of these tubes
giving rise to **Compound Glands.** If t
gland is invaginated so that these
open into the common duct, then we
Tubular Gland, of which the salivary
ples. (Figure III, D.) If these in
saccular, we speak of **Compound A**
alveolar Glands, also called **Racemose**
(Figure III, E.) The pancreas is an

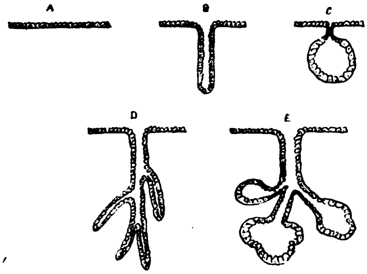

Figure III. Types of Glands. A, Simple secreting surface; B, Simple tubular gland; C, Simple saccular gland; D, Compound tubular gland; E, Compound tubulo-alveolar gland.

The nature of the secretion given off by glands serves as another basis for their classification. Some, for instance the parotids, contain mostly serous cells, and hence secrete fluid of a serous or watery nature, very poor in albumin. These are called **Serous Glands.**

Others, as the buccal and labial, containing only mucous cells, supply a thicker mucilaginous fluid, and are spoken of as **Mucous Glands.**

Still others, particularly the Submaxillary, are made up of both kinds of secretory cells and produce a mixed mucous and serous fluid. To such the name **Mixed Glands** is best applied. If one form of secretion is in excess but the other present, compound names are used, for example **muco-serous** and **sero-mucous,** the last part of the compound word designating the kind of secretion in greater abundance.

FACTORS CONCERNED IN SECRETION AND FORMATION OF LYMPH.

The substances from which secretions are formed are brought to the gland cells by the arteries but, as is the case in all tissues, the blood does not come into direct contact with the functioning cells. A fluid known as **Lymph** intervenes. Lymph is contained partly in the connective tissue spaces **(Extravascular Lymph)** and partly in closed lymph vessels **(Intravascular Lymph).** The lymph vessels do not communicate directly with the lymph spaces as was formerly thought, but end in blind saccules. Lymph resembles blood plasma in composition with the exception that the proteins are present in smaller percentage. Lymph is formed by the passing of the constituents of the blood plasma into the tissue spaces by the processes of filtration, diffusion and osmosis. Leucocytes pass into the lymph by diapedesis as before pointed out.

By **filtration** is meant the passing of a fluid through a membrane because a difference in pressure on the two sides exists. (Figure IV, A.) The endothelial cells of the blood vessels represent essentially such a membrane. On the blood side there is a considerable pressure, while the lymph spaces usually have little pressure. Formerly, it was therefore thought that these cells acted like passive membrances allowing fluid to pass simply by filtration from the side of higher pressure, the blood, to that of lower pressure, the lymph spaces. As the lymph does not entirely resemble blood plasma, however, and, as the pressure in the lymph spaces has been known to be higher than that in the blood vessels, other factors must play a part.

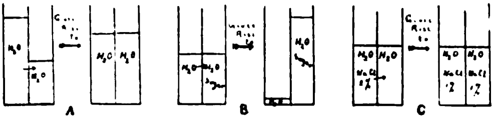

Figure IV. Diagrams illustrating the passing of Solutions through Membranes by (A) Filtration, (B) Osmosis and (C) Diffusion.

One of these factors is **Osmosis,** which means the passing of the molecules of a solvent (e. g., water), from the side of lesser to the side of greater concentration. Thus, if we select a **semipermeable membrane** and place water on one side and a sugar solution on the other, the molecules of water would pass to the side of the sugar solution and create a higher pressure on that side, the **Osmotic Pressure.** This transfer of water molecules causes a concentration of the solution on the one side and a dilution on the other side of the membrane and the passing of water ceases only when the centrations on the two sides are equal. (Figure IV, B.).

Similarly, the presence of salts, urea, sugar, etc., in greater concentration in the lymph space than in the blood may attract water from the blood, and then create a pressure even higher than that of the blood. To have this occur, however, it is necessary that these substances be present in the lymph spaces, a transfer that takes place by **Diffusion.** By diffusion through a membrane is meant the passing of substances in solution from a higher to a lower concentration. Such substances are termed **Solutes,** while the medium dissolving them is called the **Solvent.** This process goes on whenever two solutions of unequal concentrations are brought together and the solute may be a gas, liquid or solid. (Figure IV, C.)

The same physical forces are concerned in the transfer of substances from the lymph to the gland cells. It may well be imagined that, when a cell begins to secrete, the concentration of salts within the lymph is greater than in the ducts. These would then pass by diffusion to the ducts until the concentration there became equal to that in the lymph stream. Meanwhile, enough enzymes or mucin would have been added by the cells to the ducts to cause this side to exert an osmotic attraction for the water of the blood. Although all of these physical factors aid in the process of secretion, they do not satisfactorily explain the presence of such substances as are not present in the blood or lymph, e. g., hormones, ferments, mucin. Such constituents of a secretion are elaborated by the cell itself. When glands are resting, they construct these new products from the nutrient substances and oxygen supplied to them by the blood and lymph, and, when they are stimulated chemically or through nerves, these products are washed out by the water, and added to the secretions.

SUMMARY.—SECRETORY CELLS AND GLANULAR TISSUE.

I. Gland Cells—Types of

1. Serous cells—Ground glass appearance—indistinct outlines—filled wth numerous small granules. Outer border clearing first during activity.
2. Mucous cells—Few large granules—distinct outlines —during activity, cell becoming uniformly clear.

II. Substances Liberated in Secretio

1. Salts.
2. Water.
3. Enzymes.
4. Hormones.
5. Miscellaneous substances of fun neither enzymes nor hormon
6. Excretory substances.

III. Classification of Glands—

A. Morphologically
   1. Simple Secreting Surfaces.
   2. Simple Tubular Glands.
   3. Simple Saccular Glands, or
   4. Compound Tubular Glands.
   5. Compound Tubulo-alveolar ous).

B. Functionally
   1. Serous or albuminous (Par
   2. Muco-serous (Sublingual in
   3. Mixed Glands (Submaxillar
   4. Sero-mucous (Sublingual i
   5. Mucous (Buccal and Labial

IV. Factors Concerned in Elaborati

1. Filtration, the interchange ence of static pressure.
2. Osmosis, the passing of through semipermeable lower to higher concentr
3. Diffusion, the passing of a to a lower concentration
4. Metabolic changes of the c

V. Lymph—Composition and Fun

1. Water—by filtration and o
2. Salts—by filtration and diff
3. Proteins, carbohydrates, fa diffusion from blood.
4. Leucocytes—by diapedesi places of origin.
5. Excretory products and C

CHAPTER VII.

MUSCLE CELLS AND MUSCULAR TISSUE.

(Contractility).

Histologically, muscle cells are divided into three types, **smooth** or **unstriped, cross-striated** and **heart** muscle.

Smooth muscle consists of small spindle shaped cells with a single, oval nucleus quite centrally placed. They are not entirely without striation, as the name implies, but contain delicate, longitudinal fibrils with a homogeneous sarcoplasm between.

Striated muscle consists of large cylindrical cells ending in a tapering tendon. Each cell is surrounded by a **sarcolemma,** and contains many nuclei just beneath this sheath. On superficial examination, this variety of muscle cell is apparently composed of cross, rather than longitudinal striations, but it has been discovered by closer inspection that it, too, consists of longitudinal fibrils, which undergo regular thickenings, thus giving the appearance of cross-striations.

Cardiac muscle was formerly described as consisting of small, oblong cells placed end to end so as to produce a branching tissue. It is now believed, however, that these are artefacts and that cardiac tissue is essentially a continuous mass of protoplasm, spoken of as the **Syncitium.** Within this protoplasm also are longitudinal striations which also possess regular thickenings making the semblance of cross-striations. (For description of the Purkinji cells, see page ...)

It will be noticed from the above description that the protoplasm of all muscle cells is made up of a series of fibrils lying within a homogeneous sarcoplasm. This sarcoplasm probably forms the vegetative part of the cells, while the fibrils comprise the contractile elements, and, like the granules of gland cells, may be considered the functioning part. In striped muscle, these fibrils compose 9 per cent of the muscle weight, in heart muscle, 56 per cent, and in smooth muscle 72 per cent.

Chemically, muscle cells are made u
bohydrates, fats, ferments and inor
proteins, two in number, **Myosin** and
liquid state; but, after death, they
coagulation under the influence of
myosin and **myogen ferments.** The
much the coagulation of the fibrin of
responsible for the hardening of m
called **Rigor Mortis.**

Muscle cells are held together in
colloid material, and these, in turn,
nective tissue into larger and larger o
a blood and lymph supply as do the gl
lated in function by nerves. The
cross-striated muscles send impulses w
the control of the will, and, for this re
have been designated **Voluntary M**
going to smooth muscle, on the other
voluntary impulses, hence this varie
Involuntary Muscle.

CONTRACTION OF MU

One of the chief functions of mus
contract. By this is meant the chan
causes a muscle to become shorter a
contraction may be artificially obtain
the use of mechanical and chemica
nerve stimulation.

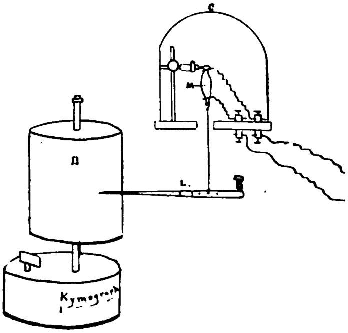

Figure V. Apparatus to study Contraction of M
bard) C, moist chambers; M, muscle; L, leve
and recording it on drum (D) of a kymog
consists of (B) battery; (K) key; (P. C.)
ondary Coil and connection with the muscle

The Myogram.—In order to study the process of muscular contraction resulting from the use of irritants, use is made of a separated muscle suspended in a moist chamber. (Figure V.) The contraction induced is then written by a magnifying lever on a kymograph. This instrument consists of a drum revolving by clockwork. The drum is covered with a sheet of glazed paper to which a layer of soot has been applied. This soot is rubbed by the lever recording the contraction, and the white curve thus obtained is called a **Myogram.**

By this means, which affords an exact method of studying the contraction process, it has been found that muscle does not respond to stimulus immediately, but that a **Latent period** intervenes. (Figure VI.) In striated muscle this period is only .01 second. The contraction then continues for .04 seconds, followed by the relaxation lasting .05 second. The entire process then takes .1 second. In non-striated muscle, however, the contraction may continue for 30 or 40 seconds and the relaxation becomes proportionately slow.

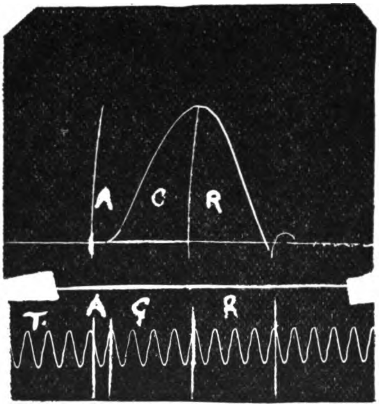

Figure VI. Myogram of Striated Muscle. T, record of tuning fork vibrating 100 times per second. A, latent period; C, contraction period; R, relaxation period.

Liberation of Energy During Contraction.—Every tissue of the body as it functionates acts as a transformer of energy. Through the blood and lymph stream energy is conveyed to the body cells, largely in a potential form, to be changed by the cells into the ki transformation may be appropriately traction process. The most evident energy is liberated during contraction ance of work. **Work** is the product by the distance it is raised. For e gastrocnemius muscle lifts 20 gram millimeters, then 200 gram-milimeters done; or, if a man's arm lifts one muscles have done one foot pound of between 25 and 40 per cent of the tot during a muscular contraction may work, but, even as it is, muscles machines for work, since the best capable of transforming only from 1 their total energy into actual work.

Heat is a second form in which during contraction. It is measured in is the quantity of heat necessary to ra 1 degree centigrade. It is estimate 70% of the total energy liberated be fact, the heat of the body is largely heat energy resulting from muscula act of shivering when the temperatur to warm the body by producing hea action, while we are apt to avoid n day in order that the stored energy formed to heat.

Electricity is a third form of ene the contraction process. The con muscle becomes negative in relation tracting, so that little electric curr flowing through our bodies. In cert tric fish and eels, this current may be used as a means of defense for be detected in other animal tissue instrument known as a galvanomete

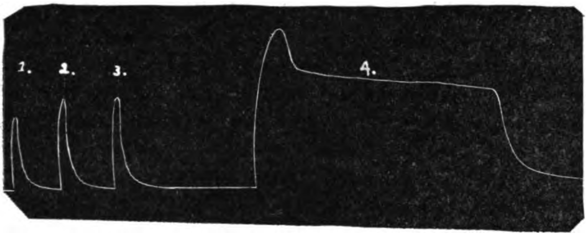

Figure VII. Tetanus of Muscle contrasted with Simple contraction. 1, 2, 3, curves of simple contraction; 4, tetanus induced by 40 stimuli per second.

Tetanus and Tonus of Muscle.—If a striated muscle is stimulated with a series of frequently repeated shocks, any one of which would call forth a single contraction, the curve, as recorded, will rise very high and remain so as long as stimulation continues. This state of gradual and continued contraction is spoken of as **Tetanus.** (Figure VII.) The quick jerking away of a finger from a hot object is the result of a single muscular contraction, but the gradual and graceful movements performed in every day life are all examples of tetanus. If a muscle is stimulated with frequently repeated shocks of so weak a character that any one of them would have no effect on the muscle, it is found that the muscle will gradually shorten slightly, a condition called **Tonus.** If a muscle is stimulated by a series of single stimuli and allowed to relax between each stimulation, it will soon be found that the completeness of relaxation becomes less; a condition spoken of as **Contracture,** which is really tonus experimentally produced. (Figure VIII.)

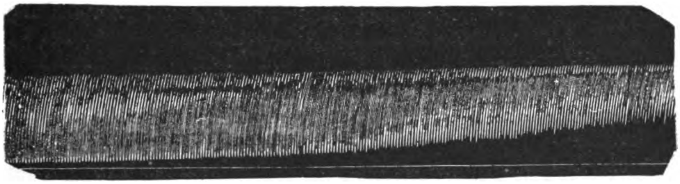

Figure VIII. Contracture of Muscle. Curve obtained by stimulating at a rate of two times per second.

Examples of tonus are found in the
and the feeling of tension during m
excitement. In smooth muscle, tonus
nounced than in the striated variety,
of its most characteristic attributes.
this will be better realized when the
muscle in the alimentary tract anc
studied.

SUMMARY.

1. **Histological Characteristics of-**
   1. Smooth Muscle Cells—Spindl
      tral nucleus; Longitudinal s
   2. Cross-striated Muscle Cells—I
      many nuclei beneath sarcol
      are regular thickenings of l
   3. Cardiac Muscle—Syncytial st
      artefacts: longitudinal stria
      ular thickenings give the
      striations.

II. **Chemical Composition.**

$\text{Proteins}\begin{cases}\text{Myosin;}\\ \text{Myogen;}\end{cases}$

Carbohydrates
Fats
Inorganic Salts
Water 72%
Myosin ferments, coagulate
(Rigor Mortis).

III. **Muscle Tissue Contains—**

Muscle Cells, Connective
Lymph channels, Nerve st

IV. **Contraction of Muscle—**

Myogram of Simple Contra
Period—Contraction, Rela
Energy liberated as (a) W
energy; (b) Heat; (c) Ele

V. **Complex States of Contractio**

Tetanus, great and prolonge
ful nature.
Tonus, state of slight or p
Contracture, Tonus experim
used in same sense as tor

CHAPTER VIII.

NERVE CELLS AND NERVOUS TISSUE.

(Irritability—Conductivity).

The nervous tissue of the body is composed of elementary units called **Neurons.** Each neuron is composed of a nerve cell-body and at least two processes, a long one, the **Neuraxis,** and a shorter one, the **Dendrite.** Each of these has an end brush or receptive organ of some kind.

The nucleated nerve cell itself is found, on staining, to consist of a fine network of neuro-fibrils which some observers have traced as continuous with similar fibrils found in the neuraxes and dendrites. In addition, there are found irregular masses of granules, the **Tigroid Substance,** which probably represents a store of nutritive material. The shape of the nerve cell varies considerably, but, in general, they may be divided into three classes, viz.: 1. The unipolar type. 2. The bipolar type. 3. The multipolar type. (Figure IX.)

The essential portion of the nerve fibers, neuraxes and dendrites, is the central core of protoplasm, the axis cylinder, which is really a continuation of the nerve cell protoplasm. Nerves are classified as medulated and non-medulated, according as the axis-cylinder is or is not surrounded by a sheath of fatty nature called the medullary sheath.

IRRITABILITY AND CONDUCTIVITY OF NERVE FIBERS.

Nervous tissue possesses to a very highly developed degree the property of irritability. This property has before been defined as the power of reacting to an irritant or stimulus. It is possessed by most living tissue; the gland cell shows it when it reacts to a stimulus by secreting; the muscle cell, when, on being stimulated, it contracts. The nerve fiber shows its irritability to

stimuli by generating and conducting
in turn causes other cells to react.

Irritants. The irritant that generat
nerve may be (a) **Physiological** or
nerve cell like other body cells is con
metabolic processes, and, in so doing,
which exhibits itself by the genera
by the cell and its transmission to
conduction. We are at least familia
ently automatic and spontaneous dis
from certain cells of the body, and
ducted to various tissues by the ner
physiological irritants. It is worth
they are discharged by the cells at
ten to thirty times per second.

As artificial irritants may be menti
Irritants, such as cutting, pinching or
b) **Thermal Irritants,** such as the ap
cold, c) **Chemical Irritants,** produc
agents and d) **Electrical Irritants,** d
a battery or an induction coil. Any
ences serves to stimulate nerves and
erate impulses and conduct these t
an irritant is applied to a sensory n
pain. Take the example of an expo
—to touch or prick this, to apply he
icals, or an electric current gives s
its irritability.

Irritability of Nerves.—This p
not always constant, but can be l
above the normal in various ways.
a nerve to the freezing point lessons
heating, on the contrary, increases
of the blood supply and using the
direct electric current are method
bility, and cocaine may be cited
drug, the use of which will accompl

Conduction and the Nerve Impuls
particular form of reaction to a sti
cells have specialized to the highe
of this property, an excitation set
body is conveyed to its most dista

takes place through the substance of the axis cylinder. The myelin sheath does not in any way aid. The exact nature of the nerve impulse is still a matter for speculation. It is not an electrical current, as was once supposed, for it will not pass if the continuity of the nerve fiber is broken by the tightening of a moist ligature, whereas an electric current will. Moreover, the conducting function of the fiber depends on its connection with the nerve cell. If a nerve is cut, the part severed from the cell loses its conductivity and irritability, but an electric current can still be readily passed through it. Nerve impulses are normally conducted at a rate of 28 to 34 meters per second, that is, much more slowly than electric currents travel. If it originates in the middle of a fiber, it is conducted in both directions, but, curiously enough, it will pass through the cell body in only one direction, so that, taken as a unit, the neuron may be said to conduct in one direction only. There is but one kind of nerve impulse, but this brings forth a variety of reactions from the different tissues, as muscles, glands, or another nerve cell. Thus, various wires may carry only one kind of electricity, but the service rendered at the terminals depends on the type of receiving instrument, whether telephone, telegraph or motor.

On this basis rests a functional classification of nerve fibers. Those fibers which carry impulses toward the central nervous system receive the name **Afferent Fibers,** while those conducting in an opposite direction are termed **Efferent Fibers.** If the afferent fibers come from a sense organ and convey the sensation of pain, touch, taste, etc., we call them **Sensory,** otherwise they are merely designated as **Reflex Fibers.** The efferent fibers are named according to their termination. Those ending in muscle cells are called **Motor,** and those which terminate on gland cells, **Secretory.** If they end on the muscular elements of blood vessels the term **Vasomotor Fibers** is applied. This class embraces **Vasoconstrictor Fibers,** which cause the circularly disposed muscle fibers in the blood-vessel walls to contract; and **Vasodilator Fibers** which produce a dilation.

In the study of vasomotor fibers we have become acquainted with the varying modes of action on the part of nerve fibers. We see that they may not only excite,

but also inhibit the action of cells. Thi
may affect any cells capable of bein
have **Inhibito-motor, Inhibito-secretory**

SUMMARY.

I. Neurons.

a) Elements of, Cell body, dendrit
ings.

b) Types of, Unipolar, Bipolar, Ste

II. Irritants.

a) Physiological.

b) Artificial (Mechanical, thermal,

III. Irritability Modified by

a) Temperature.

b) Blood supply.

d) Drugs.

e) Chemicals.

IV. Nerve Impulse, Nature of

a) Reaction between irritable nerv

b) Not an electric current for

1. Not conducted over moist
2. Rate of conduction too slo

c) Conducted both ways in nerve
nerve cell.

d) Nature of reaction not depende
receiving mechanism.

V. Classification of Nerve Fibers.

a) Morphologically—Medulated, N

b) Functionally—Afferent, (e. g., s
Efferent, (e. g., mc
motor).

SECTION III.

THE PHYSIOLOGY OF THE NERVOUS SYSTEM.

CHAPTER IX.

THE NERVOUS SYSTEM AND REFLEX ACTS.

Anatomical description, as a rule, separates the nervous tissue into two systems, central and peripheral. The former embraces the spinal cord and brain. The latter includes the nerves emerging from the central system and their ganglionic masses. Histological studies of the spinal cord show that it is made up of a central, butterfly-shaped mass of gray matter surrounded by white matter. The white matter is divided into two halves by an anterior fissure and a posterior raphe. Each half is further subdivided by projections of the gray matter, into the posterior, lateral and anterior columns. The gray matter is arranged around a central lumen, and, on each side, three horns are recognized, an anterior, a lateral and a posterior horn. (Figure IX.)

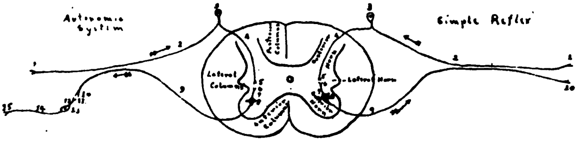

Figure IX. Nervous Elements involved in Simple Reflexes and the Autonomic System. 1. Peripheral nerve ending; 2, afferent axon; 3, posterior root ganglion cell; 4, neuraxis; 5, spinal cord terminal; 6, nerve ending; 7, dendrite; 8, anterior horn cell; 9, efferent neuraxis; 10, nerve ending. On left half of diagram 9, a preganglionic fiber; 10, nerve terminal; 11, another nerve ending; 12, dendrite; 13, ganglionic cell; 14, post-ganglionic fiber; 15, nerve terminal. Types of Nerve Cells—3, a unipolar cell; 8, a stellate cell; 13, a bipolar cell.

In order to obtain a true physiological conception of the nervous system, it becomes necessary to comprehend that those so-called nervous systems, central and peripheral, are not separate entities but are really one and continuous. Throughout the body, nervous tissue

is scattered in the form of nerves, v
system it is gathered into masses ar
The element of this nervous tiss
There is no continuity of structure
ferent neurons, but merely a contact
Synapse. Chains of neurons always f
the impulse being conducted from on

Simple Reflexes.—The simplest ex
neurons is found in a simple reflex a
pulse is sent from the periphery to
back from the cord to the periphery
being involved. (Figure IX.) Whe
applied to the skin or to some inte
impression is made on some form c
may be a Paccinian corpuscle, a t
cell or an ordinary nerve subdivisi
the impulse is carried up the ner
spinal cord. This second link is
Afferent Fiber. Just before enteri
it comes under the influence of a
the **Posterior Root Ganglion Cell,** a
another axon passes into the poster
matter. In the central gray, it sp
shaped or basket-like ending whic
contact with the end basket and d
cell situated in the anterior horn a
the **Anterior Horn Cell.** This cel
another impulse passes out by the
through a modified nerve ending
muscle. There are, therefore, tw
concerned in conducting a simple
trunk is a cable of nerve fibers bou
nective tissue. Each fiber, however
pulse, independent of those by its s
Only striated muscles possess so s
as has been described. Nonstr
muscle, glands, etc., have a secon
between them and the spinal cord.
cell body which is of the bipolar ty
sympathetic ganglia. Langley has
Autonomic for this system of fibers
fiber does not connect directly with
The fiber carrying impulses from th

is spoken of as the **Preganglionic fiber,** that carrying the impulse from the ganglion to the periphery as the **Postganglionic fiber.**

COMPLEX REFLEX ACTS.

Few reflex processes are as simple as those we have studied, in fact nearly all of them introduce a number of complicating factors. In the first place, more than one muscle is concerned in every muscular action. Thus a certain amount of co-ordination is required between the various muscles acting. If a frog, the brain of which has been destroyed, is suspended from a hook it will exhibit no movements unless irritated. If its toe is pinched or acid applied to the foot, it will withdraw the leg. If acid is placed on the legs or groin by bits of filter paper a co-ordinated attempt will be made to dislodge the paper. This requires a regulation of the muscles so that each acts in its turn to produce flexion of the proper degree. If the nerves going to the leg are dissected out and stimulated by an electric current, the leg will not flex but extend. The reason is, that, in this case, both flexor and extensor muscles are stimulated and, as the latter set are the stronger, the leg extends. In a normal reflex, the afferent impulse excites not only the flexors but also causes an inhibitory impulse to be sent to the extensor muscle of the leg. (Figure X.)

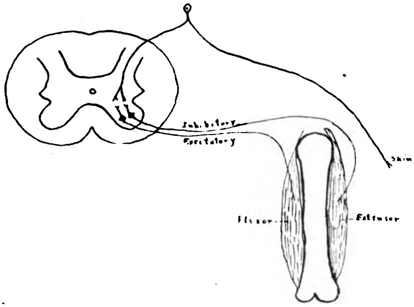

Figure X. Complex Reflex involving Excitation and Inhibition.

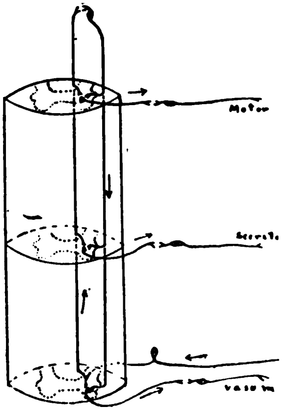

Figure XI. Complex Reflexes to other L

In the second place, the exciting
of an impulse is not limited to the
which it enters, but it may stimulate
rons through fibers passing up and
this way synapses may be formed
send impulses to various tissues,
Figure XI, motor, secretory and
may be sent out as a result of a singl
The nerve cells supplying groups o
sels or gland cells, as a rule, lie cl
central nervous system, and to sucl
cells the term **Nerve Center** is applie
In the third place, reflexes are
the connection between each afferent
responding efferent ones is not direc
represented, but occurs through a
fibers situated entirely within the
are two types of these cells, physio
Their cell bodies are situated in tl
its vicinity. Those cells whose fiber
neurons of the **same side** of the c
other level, are called **Communicatin**
whose fibers connect with neurons
at that or another level, are terme
(Figure XII.)

CHAPTER X.

THE TRANSMISSION OF IMPULSES TO THE BRAIN.

Before discussing the conducting function of the spinal cord, it becomes necessary to detail further the structures involved in this process.

The Columns of the Spinal Cord.—The columns of white matter of the spinal cord containing only nerve fibers are concerned in the conduction of impulses up and down the cord, while the gray matter containing nerve cells as well as fibers takes care of the reflex processes.

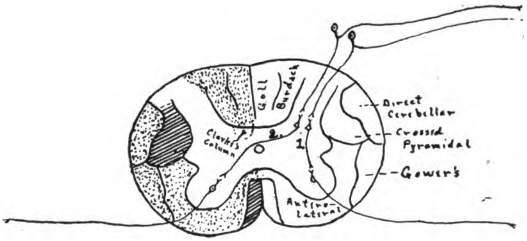

Figure XII. Columns of Spinal Cord. Shaded columns indicate descending tracts and dotted columns the ascending tracts. 1, Communicating and 2, Commissural cells of gray matter.

There are six main ascending columns arranged on each side of the central gray. Of these four carry impulses up, **Ascending columns,** and two carry them downward, **Descending Columns.** Their location and names may be learned by reference to figure XII. They may be summarized as follows:

Ascending Tracts.

Goll and Burdach
Direct Cerebellar
Gower's Tract
Antero-lateral Tract

Descending Tracts.

Direct Pyramidal
Cross Pyramidal

The Brain and Its Sub-divisions.—
from which impulses are conducted, is
tinuation of the spinal cord. It consis
visions, the cerebrum, cerebellum an
The **cerebrum** forms the largest s
brain. It is divided into two hemisph
tudinal fissure. Like the spinal cord,
gray and white matter, but the arrang
the white matter being internal to t
The cerebral cortex is not smooth
indentations and invaginations so t
divided into lobes and these into gyri
chief lobes are the frontal, temporal a
most important fissures are the lon
the brain into two hemispheres, the
passing backward on each side an
Rolando passing upward. The regi
Rolandic fissure is called the **Pre-Rola**
of the cortex, that posterior to the
Rolandic or **body-sense area.*** (Figu

The Cerebellum.—The cerebellum
tex of gray thrown into laminated
stratum of white matter. It is comp
hemispheres separated by a vermifor

The Medulla.—The medulla connec
cerebellum with the spinal cord. It c
dorsal surface several thickenings o
nuclei of **Goll** and **Burdach.** Above
oblong space bounded above by the
peduncles and below by the **inferior c**
In the floor of this space, which is
ventricle, are situated the nerve
respiration, the heart, blood vessels,
ber of important functions. (Consult

The Basal Ganglia.—When the c
are removed the dorsal surface
Anatomy) just above the superior
shows a number of other masses
situated and termed the **Basal Gangl**

---

*The Rolandic fissure is also designated as
areas in front and behind as the pre-central and

from below upwards a) the **inferior corpora quadrigemina** connecting laterally with the **internal geniculate bodies,** b) the **superior corpora quadrigemina** intimately connected laterally with the **external geniculate bodies,** and c) the **optic thalami.** Radiating above these masses are strands of white matter which connect with the cerebrum when not removed. This is the **corona radiata** of each hemisphere.

THE BODY SENSATIONS AND THEIR CONDUCTION TO THE BRAIN.

The sensations carried to the brain by the spinal cord are four in number, temperature, pain, touch and muscle sense. These are designated as **body sensations** as distinguished from the **special sensations** such as sight, taste and hearing.

If a drawn out and pointed glass tube is filled with water at 40 degrees centigrade and applied to the skin, points can be located where its application will give a sensation of warmth, others where it will give a sensation of cold, still others where it feels painful, still others where it is merely felt as a weight. By this method it has been determined that there are special nerve terminals in the skin for different sensations and there is evidence that these sensations are conducted by separate nerve fibers. By **muscle sense** is meant the sense which enables us to tell where a limb is in relation to the rest of the body or enables one to estimate the weight of objects.

Path of Conduction in the Spinal Cord.—In tracing the courses by which impulses are conducted to the brain, the path will be more readily followed by continued references in figure XIII.

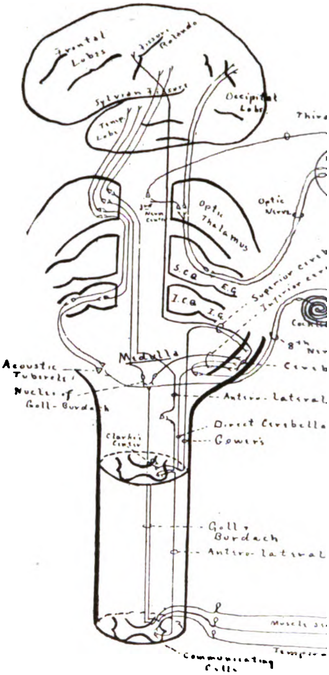

Figure XIII. The Ascending Tracts to the Cereb
tion of the Basal Ganglia.

The Afferent Path.—One group of
from the periphery stops at the pos
cells and from these axons are sen
horns of the spinal cord and soon e
Goll and Burdach and by them p
Here they end (a) in cells of the nuc
dach whose fibers pass to the oppos
sate) and reach the cerebral cortex, a
of this nucleus whose fibers pass to t
By this path the sensations of **Touc**
are conducted to the cerebrum and

Another type of afferent fibers e
columns as the previous group. Th
distance up the columns of Goll and
into the gray matter and terminate

in **Clarke's column of cells** at the base of the posterior horn. From these cells fibers pass up the cord in the direct cerebellar and Gower's tracts and those of the first named tract reach the cerebellar cortex through the inferior and those of the last named tract through the superior cerebellar peduncles. These tracts conduct muscle sense impressions.

A third group of afferent fibers end soon after their entrance into the gray matter, around communicating cells which, in turn, send fibers up the antero-lateral tract, etc. In this way a tract of short fibers is formed with many switching stations interposed. These fibers finally reach the medulla, decussate and then pass to the cerebrum. By this route are conducted the sensations of pain, temperature and probably touch.

All the body-sense sensations are projected on the brain in the area just posterior to the Fissure of Rolando, called the post-Rolandic area.

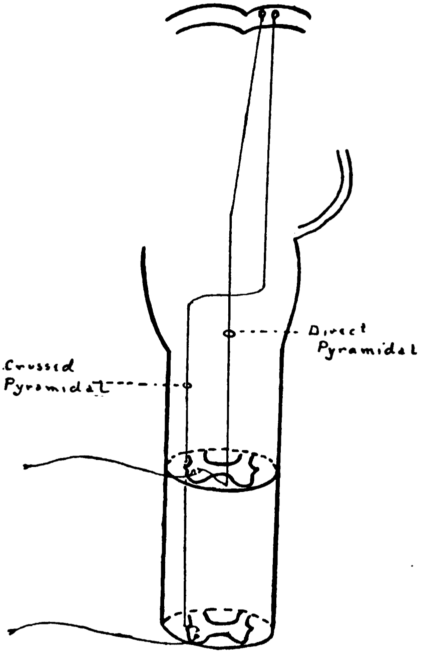

Figure XIV. The Descending Tracts.

The Efferent Path.—Figure XIV. The cortical cells situated in front of the Fissure of Rolando, or in the pre-Rolandi area, send fibers down the cord. Most of these pass down to the medulla, there cross to the opposite side and pass down the spinal cord in the **crossed pyramidal tract**. At various levels they end around **anterior horn cells** of the cord, and these, in turn, send impulses to the muscles. Other fibers do not cross in the medulla but pass directly down the cord in the **direct pyramidal tract.** Lower in the cord, they one by one decussate and end around cells in the anterior horns which also send fibers to the muscles.

CHAPTER XI.

THE FUNCTIONS OF THE BASAL GANGLIA AND THE CEREBELLUM.

Not all body sense impulses are carried directly upward to the post-Rolandic areas by fibers arising from the cells of the nuclei of Goll and Burdach. (Figure XIII.) Some of them end around cells of the **Optic Thalami,** and from these fibers pass to the cerebrum by the Corona Radiata, thus making these bodies act as relay stations for body sense impressions.

In the second place, the optic thalami together with the superior corpora quadrigemini and external geniculate bodies serve as relays for visual impressions. Light strikes the cells of the retina of the eye and stimulates them to send impulses by fibers running in the **optic nerve.** Some of these transmit their impulses to other cells situated in the **external geniculate bodies,** others stimulate cells of the **superior corpora quadrigemina** and still others stimulate those of the **optic thalami.** From all of these cells, fibers pass to the occipital lobe of the cerebral cortex in which is located the **optic center.** In the third place, the optic thalami act as a reflex center for the pupil of the eye **(Pupillary Reflex).** The reflex is completed by the retinal impressions stimulating cells of the optic thalami which excite cells giving rise to the third nerve, which supplies the pupil. The nature of these reflexes is such that the iris contracts when the light becomes bright and relaxes when the light is dim, or in darkness.

The **inferior corpora quadrigemina** and the **internal geniculate bodies** are intimately associated in the central conduction of sound impressions. Through the mechanical leverage of the bones in the middle ear, the cells of the cochlea are stimulated by sound vibrations. These are transmitted by the **auditory part** of the **eighth nerve** to the cells of the acoustic tubercle situated in the medulla whence impulses are carried by fibers forming synapses (a) with cells of the internal geniculate bodies

and (b) with cells of the inferior co
Fibers leave these cells to end on th
the cerebral cortex where the center

FUNCTION OF THE CER

Muscle sense and touch impressio
not only to the cerebrum, but some
the cerebellar cortex. These im
proper correlations have much to
the equilibrium of the body. The
librium, however, are the **semi-circu**
ternal ear. Unbalanced states of the
to be sent from the cells of these ca
tibular portion of the **eighth nerve**
the medulla. These cells send impu
cortex.

These equilibrium impressions aff
bellar cortex and cause them to trans
of the superior cerebellar peduncle
of the cerebrum. In this manner a
turbed equilibrium, as recorded th
sense, and vestibular impressions
tends to be counteracted by a volun
induced by the motor cells of the c
ure XIII.)

CHAPTER XII.

THE FUNCTIONS OF THE CEREBRUM.

The peripheral sensations conducted upward through the spinal cord are carried to the post-central area of the cortex, and motor impulses pass downward from the precentral area to the periphery. Thus the cerebral cortex acts as a terminal depot, to the cells of which, impulses come and, from which, they deport. It possesses the more important functions of recording, storing and associating these impulses which enable us to become conscious of events and objects. This mental development is entirely a post-natal affair. The cerebral cortex at birth contains a definite number of cortical cells which never increases after birth. This number may vary with different individuals and this fact may explain the reason that all people are not equally intellectual. Mental activity develops after birth because a change in the physical and chemical makeup of the cells occur in consequence of the oft-repeated incoming impulses from the periphery. Thus, in addition to a fair supply of cells at birth, a proper cell development is necessary. A fair number of brain cells well utilized are of greater advantage than a large number that are untrained.

The child is known to execute movements even before birth. These are largely reflex in character and are due to the stimulation of the skin of the child by the mechanical pressure of the uterus. Thermal stimuli are foreign to the child at that time, but become operative as soon as it is exposed to the colder atmosphere. All of these bombarding stimuli cause reflexes, and some are also carried to the cells of the cerebral cortex by fibers running up the cord, and these induce changes in the cells which, for want of a better term, may be called **Impressions.** Similarly, stimuli are sent in through the auditory, olfactory and optic tracts. When the cortical cells have repeatedly had the impressions set up by bearing a sound or seeing an object, they finally come to recognize these and **Memory** for **Impressions** has developed. It thus

comes about that in widely separated
bral cortex different impressions ar
cells of the post-Rolandic area have t
ture impressions and also pain and r
in them; the occipital lobes hold the ir
the superior temporal lobes the im
etc. (Figure XV.)

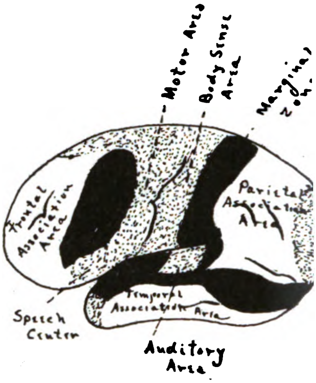

Figure XV. The Areas of the C

The memory impressions so widel
out the cortex next become somewh
sociated. An infant is attracted by
the impression is stored in the te
attracted by its glitter and shape, a
are stored in the occipital lobe. H
and hardness, and these impressio
cells of the post-central area. A
finally become connected throug
found in the zones immediately sur
sion areas and called the **Marginal**
ciation the idea of the object "bell
the sound or sight of a bell no long
sion of a sound or sight, but bri
whole idea of the object "bell."

Spoken words as well as objects
pression by their repetition. They
of the inferior frontal lobes **(Broca'**

ciation between the object and the spoken word, bell, stir up the same idea of the bell. The last step occurs when the word is repeated by the child. This requires further an association with the center governing the muscles of the tongue, which is situated in the pre-Rolandic area.

We go through life collecting and storing impulses and impressions. As a result, a great number of combinations of associations can occur and a great number of ideas develop. In youth the cells are much more susceptible and this is obviously the time to create the proper impressions. These, by becoming more and more associated during later life, determine the moral and intellectual capacity of the individual. The varied association of a few erroneous impressions from early life is capable of forming the basis of a multitude of wrong ideas and acts in later life.

By associating ideas in an orderly manner, so that we reproduce something before learned, **Memory** develops, but, when we produce something new, a reasoning process is inaugurated. These intellectual processes, which reach such great development in man, are the result of more complex associations than those occurring in the marginal zones. Flechsig claims that all cerebration depending on body sense impressions, such as appetites, desires and ideas of morality occur in the frontal lobes, while experiences derived from visual and auditory impressions, such as music, are associated in the area posterior to the body sense area, i. e., in the parietal lobes. (Figure XV.)

SUMMARY.

Reflexes.

1. Simple (Comprising two neurons).
2. Autonomic (Comprising three neurons).
3. Complex.
    a) Incoming impulse producing both excitation and inhibition.
    b) Incoming impulse forming synapses with many neurons at different levels.
    c) Incoming impulse causing efferent impulses through series of cells.

Spinal Cord.

- Gray Matter.
  - Posterior Horn contains:
    - Communicating Cells.
    - Commissural cells.
    - Clarke's column cells.
  - Lateral Horn contains:
    - Vasomotor cells.
    - Secretory cells.
  - Anterior Horn contains:
    - Motor cells.
- White Matter.
  - Ascending Columns:
    - Goll and Burdach to cerebrum and cerebellum.
    - Direct Cerebellar to cerebellum.
    - Gower's to cerebellum.
    - Antero-lateral tract to cerebrum.
  - Descending Columns:
    - Direct Pyramidal.
    - Crossed Pyramidal.

Sensations.

- Body Sensations:
  - Pain.
  - Touch.
  - Temperature.
  - Muscle Sense.
- Special Senses:
  - Sight.
  - Smell.
  - Hearing.
  - Taste.

Functions of Basal Ganglia.

- Optic Thalami:
  1. Relay Stations for body sense impressions.
  2. Relay Station for visual Impressions.
  3. Reflex Center for pupil.
- Superior Corpora Quadrigemina and External Geniculate Bodies.
  1. Relay Stations for Vision.
- Inferior Corpora Quadrigemina and Internal Geniculate Bodies.
  1. Relay Stations for Sound.

Functions of the Cerebellum.

1. Receives Touch and Muscle Sense Impressions.
2. Receives Impressions of Equilibrium from Internal Ear.
3. Transmits impulses to motor cortex of cerebrum.

Functions of Cerebrum.

1. Receives sensory impressions in
    - Optic area in occipital lobe.
    - Auditory area in superior temporal lobe.
    - Speech center (Broca's area) in inferior frontal lobe.
    - Body sense area in post-Rolandic area.
2. Associates Impressions in marginal areas.
3. Deeper association in
    - Temporal Lobe.
    - Frontal Lobe.
    - Parietal Lobe.
4. Sends motor impulses from pre-Rolandic areas.

SECTION IV.

PHYSIOLOGY OF DIGESTION A

CHAPTER XIII.

THE MOVEMENT OF FOOD IN TARY TRACT.

The digestion of food occurs in th
which may be said to comprise, consec
pharynx, esophagus, stomach, jejunu
ascending, transverse and descending
(Figure XVI). The alimentary trac
so arranged that those of the upper
mouth, pharynx and upper third of
striated, while the rest of the tract is
non-striated type, insuring slow move

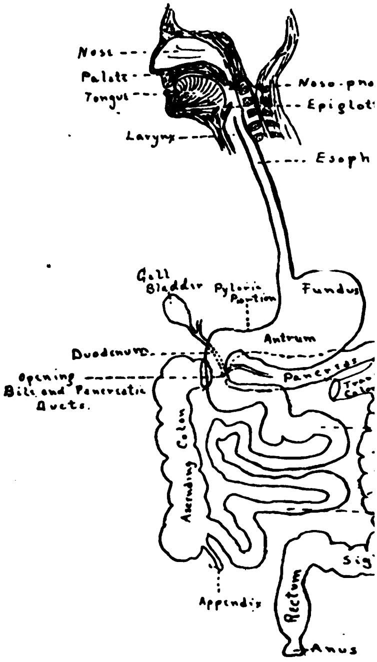

Figure XVI. General View of the Digestive

The muscle fibers of the entire tract are arranged in two continuous layers, the outer longitudinal, the inner circular. These layers assume different thicknesses in various portions, and so need further description. In the esophagus, the longitudinal layer composed of striated muscle in its upper fifth, of both varieties in the second fifth and of non-striated muscle in the lower three-fifths, is a very thick layer. Internal to this is a much thinner circular layer, composed of striated muscle only in the upper third. This gradually shades into the non-striated variety found in the lower half. At the entrance into the stomach the circular fibers suddenly become much thicker and this layer with the mucous membrane covering it forms the **Cardiac Sphincter,** or gate arrangement of the stomach. The longitudinal fibers continue downward in a thinner layer and form the outer longitudinal coat of the stomach. The circular layer beyond the sphincter, divides indistinctly into two layers, one circular, the other oblique. The circular layer is fairly well developed in the upper or fundic end of the stomach, but even more markedly in the lower or pyloric portion. Between the duodenum and stomach another thickening of these muscle fibers occurs, and this gives rise to the **Pyloric Sphincter,** which closes the stomach below. The muscular coats of the intestines are continuous with those of the stomach. Here the circular coat is the heavier. In the large intestines the longitudinal fibers have been collected into three visible, longitudinal bands which are equidistantly placed around the tubes. (Figure XVII.)

MASTICATION.

It is the function of mastication to more completely subdivide food and so allow a more perfect admixture with the digestive juices. In order that mastication can be properly carried on, the teeth should not only be present and properly set, but the dividing aparatus must also be continuously fed, and the food triturated with saliva and formed into a bolus for swallowing.

The teeth, 32 in number in the permanent set, are arranged on the upper and lower jaws in two curved rows in such a manner that each upper tooth strikes two lower teeth. The incisors, four on each jaw, occupy the

central and anterior portion of the d
are chisel-shaped and used to cut the
lumps. Lateral to the incisors are the
in each jaw. They are adapted by t
and their adjustment to the tearing o
which, it must be confessed, etiquet
lessened in man. The bicuspid teet
in each jaw and the molars numberin
tened and cusped crowns which form
well adapted to the grinding of food.

The upper jaw remains stationary, t
being moved by two sets of voluntary
the mandible. One set causes an ele
sion of the jaw utilized in cutting wit
other causes the lateral motion necess
ing action of the molars. The buccal
cles also contract, pushing the food bet
surfaces, an event of no little importa
During mastication the food is moist
by the saliva. It is interesting to obs
ous, watery secretion is poured into
near the molar teeth, a point where
food is best accomplished. Finally, t
with a layer of mucus from the mou
lubricated, is swallowed.

DEGLUTITION.

Swallowing is accomplished in th
ponding to the three anatomical divis
ynx and esophagus. The passage of
mouth is a voluntary act, though usu
performed. It occurs by the forcibl
tongue from tip to base against the
pushes the food into the pharynx. T
through this portion of the tract inv
plex series of muscular contractions.
municates with the mouth, nose and
less resistence than that leading
esophagus. In order that food may
last mentioned, it is necessary that th
be at least partly closed. The comm
mouth is shut off by the approximat

to the palate, and the simultaneous contraction of the anterior pillars of the fauces. The nasal cavity becomes separated from the pharynx by the elevation of the uvula and soft palate forming a sloping surface. The contraction of the posterior pillars of the fauces also aids. The shutting down of the epiglottis was long supposed to be the mechanism for closing off the larynx. It has recently been shown, however, that it is not by any means the only manner of accomplishing this, though normally, it probably does possess that function. The depression of the base of the tongue and the elevation of the larynx felt readily in swallowing, tend to close the opening. The third stages of swallowing is carried on by the esophageal muscles, which are continually in more or less of a condition of tonus. From this state they may rela,x i. e., be inhibited or contract farther, i. e., be stimulated. After the bolus of food has entered the esophagus, the circular muscles contract behind it and move it to another segment while the longitudinal muscles contract ahead and thus widen that part of the tube which is to receive the bolus. In this way food is pushed down the esophagus from segment to segment. Such a wave of contraction is spoken of as **Peristalsis.** A peristaltic wave carries a solid bolus of food down the esophagus to the cardiac sphincter in six seconds. The sphincter then relaxes and allows the food to enter the stomach. Liquid food does not pass down in this way. The initial force of swallowing, aided by gravity, is sufficient to send it down the esophagus in about .1 second. Arriving at the cardiac sphincter, it is not usually allowed to enter until the after-coming peristaltic wave arrives 6 seconds later, and allows the sphincter to open.

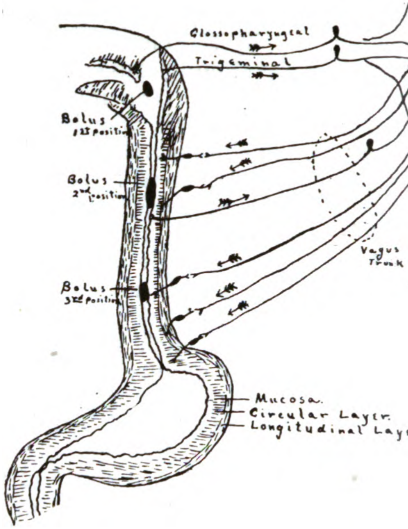

Figure XVII. Diagram showing Muscular Arrangem
Stomach and the reflex regulation of Swallowing.

The passing of the peristaltic wave fr
ward is at least largely regulated by the
system. This was shown by Mosso, w
unanesthetized dogs, found that, if a
esophagus was cut out, the wave wou
and pass on. The reflex process concer
stage of swallowing is somewhat as follo
The nerve endings of reflex fibres in th
brane of the uvula and pharynx are st
mechanical pressure of a bolus of food
then carried to the medulla by afferen
in the glossopharyngeal and trigemina
cells not definitely localized in a swallo
stimulated and send out exciting impuls
efferent fibres in the vagus. These go,
nomic system, to the circular muscles
causing them to constrict and to the lo
ahead of it making them contract. In
of the esophagus, the bolus stimulates

the mucous membrane and afferent fibers pass in the vagus to the medulla, whence efferent fibers pass out by the same nerve and excite a reflex in the circular and longitudinal muscle fibers, similar to that described above. In addition, an inhibitory impulse is sent out to the cardiac sphincter which causes it to relax from its continuous state of tonus, allowing the food **to enter** the stomach.

THE MOVEMENT OF FOOD IN THE STOMACH.

Anatomical considerations: The esophagus joins the stomach at the level of the seventh costo-sternal junction. The upper portion of the stomach, the **Fundus,** reaches up to the sixth rib. Recent X-ray investigations indicate that the long axis of the normal stomach is vertical instead of horizontal as it is frequently pictured. In the lower portion of the stomach, it will be recalled, the circular muscle fibers are especially well developed, and to this portion, marked off from the fundus by a slight constriction, the term **Antrum** or **Pyloric End** is applied. Experiments have shown that unless filled with gas, the stomach is collapsed at the completion of digestion. As bolus after bolus of food is introduced, it so happens that each mass passes to the center of the food already present in the fundus of the stomach. Gradually the tension of the fundic walls is increased, but no marked contractions occur. Food stays here as in a reservoir and is not mixed with digestive juices. Slowly it is pushed on into the antrum by the continuous tonic contraction of the fundus. In the antrum a thorough mixing of the food with the gastric secretion occurs, and within two or three minutes it is reduced to a semisolid mass called **Chyme** by the active churning of the musculature of the antrum.

During all this time the pylorus remains closed. It now opens in a remarkable way, according to Cannon. In order to understand this, it is necessary to anticipate. The gastric juice is acid in reaction. A portion of this acid is used to neutralize the alkaline saliva which is swallowed, and a portion combines with the proteins taken in. Any amount in excess of this is present as free acid in the chyme. As soon as this free acid exists, nerve ends in the pyloric mucosa are s impulses are carried to the medulla an are brought back which inhibit the Chyme then passes into the duodenu tion of the antrum. In order to preve has not been properly acidified and passing out, another reflex is set up duodenum, which closes the sphincte bohydrates remain in the stomach a proteins, while fats remain longest. rapidly. In a mixed meal the exit ti of the various times of exit of all.

MOVEMENTS OF THE SMAL

The muscular mechanism of the i alike to the proper admixture of food to its onward disaplacement. The said to be of two kinds 1) **Rythmical** **Peristaltic.**

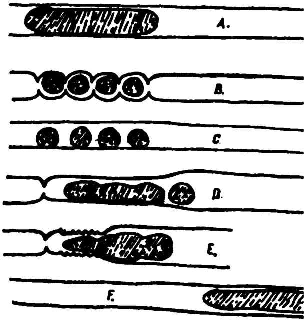

Figure XVIII. Diagram showing Subdivision and Small Intestines. Letters referred to in Text.

A mass of food injected into t quiescent for a short period. (Figure number of indentations into the mass ized constrictions of the circular fibe B.) As these constrictions become has been subdivided into several s the time that these constrictions cease, others at once occur between them, forming new segments of food and pushing the masses before formed together again. It will be seen that this movement is entirely a local one and moves the food onward but very little, its chief function being the dividing and redividing so as to bring the food into intimate contact with the digestive juices. (Figure XVIII ,C.)

After the rythmical segmentation has gone on for several minutes, the whole mass is swept on to another portion of the intestine by the peristaltic wave. Peristalsis is brought about by a constriction of the circular fibers behind the whole mass of food at the same time that a relaxation occurrs in front. (Figure XVIII, D.) Obviously this favors movement of the bolus onward. To complete the movement, the longitudinal fibers, using the constriction behind the mass of food as a fixed point, contract and pull the intestines over the food much as a glove is slipped over a finger. (Figure XVIII, E and F.)

Nervous Regulation.—The segmenting movements of the intestine result from a direct stimulation of the circular fibers and occur without the intervention of any nerves. The peristaltic movement, however, involves a series of stimulations and inhibitions which could not be co-ordinated without a nervous mechanism. In the submucosa and between the muscular layers are two sets of nerve plexuses, those of Meisner and Auerbach. The nerve fibers from some of these cells end in the mucosa, those from others in the muscles. Various irritants in the intestines stimulate these nerve endings in the mucosa and cause the ganglionic cells to send out exciting impulses to the circular muscles behind the bolus, exciting impulses also to the longitudinal muscles in front of the mass, but inhibitory impulses to the circular muscles ahead. Thus what may be regarded as a **Peripheral Reflex** is induced. These intrinsic ganglia are further influenced by the nerves from the central nervous system. The vagus nerve carries excitatory impulses which stimulate peristalsis and the sympathetic system contains fibers which inhibit the movements of the intestines.

Intestinal movements are inaugurated b
tants of the intestinal tract. Coarse, solid
ble foods supply mechanical irritants.
stances generated in the digestive tract
hydrogen suphide, carbon dioxid) as w
products and drugs (calomel) act as che

THE MOVEMENT OF FOOD IN T INTESTINE.

Food which has entered the cecum
intestine is carried up the ascending c
transverse colon and down the desce
peristaltic waves, similar to those occurr
intestine. To this movement is added
stalsis, which carries food in the opposit
bringing the food many times into intim
the walls of the intestine. This anti-
normally occurs only in the ascending
colon, but, when foreign substances are
the rectum, as in enemata, a reversed p
also found. The antiperistaltic wave
allows food to pass back further than th

DEFECATION.

The unabsorbed food is finally pres
the rectum and is expelled by the act of
rectum is guarded by two sphinctors.
sphincter is simply a thickening of cir
mucosa, but the external is composed
posed striated fibers under a continuo

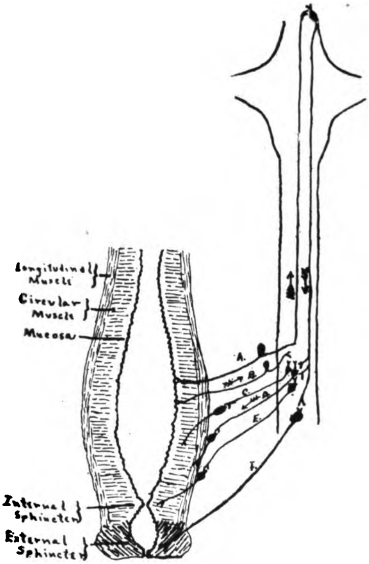

Figure XIX. The Nervous Control of Defecation.

In the early years of life, defecation is entirely a reflex act, with its center in the lumbar cord. Fecal material accumulating in the rectum stimulates afferent-reflex fibers in the mucosa which excite efferent inhibitory impulses to the internal sphincter, causing a relaxation from its tonic state. At the same time, efferent impulses excite the muscles of the rectum causing them to contract and expel the contents through the relaxed sphincter. (Figure XIX.)

In the adult, a mechanism for the control of defecation has developed. Material gathered in the rectum not only causes a reflex, but, as more sensory fibers become medulated, impulses are sent up the cord to the cerebrum and there cause the sensation of fullness or even distress. From the cerebrum, impulses pass down the cord again, which have the functions (1) of inhibiting the reflex act and (2) of voluntarily closing the external sphincter through anterior horn cells of the cord. When convenient and desirable this cerebral influence is removed

allowing the feces to be expelled. Thus
comes a voluntary act; first, because the
tion may be adapted to convenience an
place, the rectal muscles are aided by an
intra-abdominal pressure. This is acc
deep inspiration with closed glottis, the
ing movement.

SUMMARY.

I. Mastication Involves:

Presence and proper arrangement of
Up and down as well as lateral move
Counteraction between buccal and
feed teeth.
Trituration with saliva into a bolus.
Lubrication of bolus with mucus.

II. Swallowing Involves:

1st Stage—
Pushing food through mouth by
2nd Stage—
Closure of nose by elevation of
Closure of mouth by approxima
palate.
Closure of larynx by closure of
of larynx and descent of b
3rd Stage—
Longitudinal muscles widen, tu
Circular muscles constrict tube
Controlled by central nervous s

III. Stomach Movements:

A. Fundus.
Entrance of food into center of t
Tension of walls slowly pushing
No peristalsis.

B. Antrum.
Vigorous peristalsis.
Mixture with digestive juice int
Pyloric sphincter controlled by

IV. Small Intestinal Movements.

Rythmical Segmentation of food by circular muscles.

Relaxation of these muscles.

Peristaltic wave starts, consisting of:
- Contraction behind bolus.
- Relaxation of circular muscles ahead.
- Intestine pulled over mass by longitudinal muscles.

Nervous Control:
- Rythmical segmenting movements due to direct muscular effect.
- Peristaltic wave originated by plexuses in wall.
- Central nervous system further controls movements.

V. Movements of Large Intestines.

Segmenting Movements absent.

Peristaltic wave similar to that of small intestine.

Antiperistaltic wave except in descending colon.

VI. Defecation.

In Infant, Reflex causing
- a. Stimulation of rectal muscles.
- b. Relaxation of internal sphincter.

In Adult.
- Defecation prevented.
  - a. Reflex inhibited from cerebrum.
  - b. External sphincter voluntarily closed.
- Act involves voluntary factors.
  - a. Excitation of reflex from cerebrum.
  - b. Opening of external sphincter.
  - c. Increasing intra-abdominal pressure by straining.

CHAPTER XIV.

THE CHEMICAL CHANGES IN DIGESTION.

It is the purpose of digestion to change the complex fod stuffs, carbohydrates, fats, and proteins into simpler and more soluble forms. To accomplish this ferments are secreted by the various glands whose ducts open along the alimentary tract.

THE SALIVA, ITS SECRETION, COMPOSITION AND ACTION.

The saliva is the mixed product of a number of glands discharging into the mouth. In man there are three chief parts of such glands. The parotid glands are situated just anterior to the ears and open into the mouth by Stenson's duct opposite the second upper molar. They are compound alveolar glands with a serous secretion. The submaxillary glands are situated beneath the lower jaw and open by Wharton's duct at each side of the frenum of the tongue. They are compound tubular glands with a mixed secretion. The sublingual glands, situated beneath the tongue, open by numerous smaller ducts called the Ducts of Rivini. In man they are compound tubular glands of the sero-mucous type. Besides these, the lip, the tongue and the mucous membrane of the mouth and pharynx are covered by numerous unnamed simple glands which add more or less mucous secretion to the saliva.

Since saliva is a mixture of secretions from a number of glands, it must vary in composition from time to time, depending on which glands are most active. The parotid gland secretes a thin watery fluid containing few salts, small amounts of albumin and an enzyme, **Ptyalin.** The submaxillary and sublingual glands secrete a more viscid, often a stringy fluid rich in mucin.

Composition.—Mixed saliva is alkaline in reaction and contains the following ingredients: mucin, ptyalin, albumin, also chlorides, sulphates, carbonates, phosphates and suphpocyanides of sodium, potassium and calcium.

Calcium carbonate is held in solution by free CO_2 and, when this is liberated in the mouth, the calcium carbonate is precipitated and often gives rise to calcareous excresences on the teeth, called **Tartar.**

Nervous Control.—It is a well known fact that the flow of saliva is started, not only by the taste, but also, by the sight or even thought of food. This results from a reflex process diagramatically shown in figure XX. Afferent impulses are carried to the medulla from the anterior portion of the tongue by fibers running in the lingual nerve, and from the posterior portion of the tongue by those running in the glossopharyngeal. Similarly, impulses may be conducted centrally by fibers of the optic, olfactory or auditory nerves. Any or all of these incoming impulses stimulate two groups of cells in the medulla known as the secretory and vasomotor centers. The cells located in the secretory center, thus stimulated, send out impulses by their efferent fibers. Some of these terminate around ganglion cells of the sublingual ganglion, the fibers of which cells pass on to the sublingual gland and bear the impulses to the gland cells. Other fibers pass from the secretory center directly through the sublingual ganglion and conduct their impulses to ganglion cells situated in the hilum of the submaxillary gland, whence they are again conducted by short fibers to the submaxillary gland cells. Both glands, as will be observed, have a third neuron interposed in their nerve supply making it an **autonomic** one.

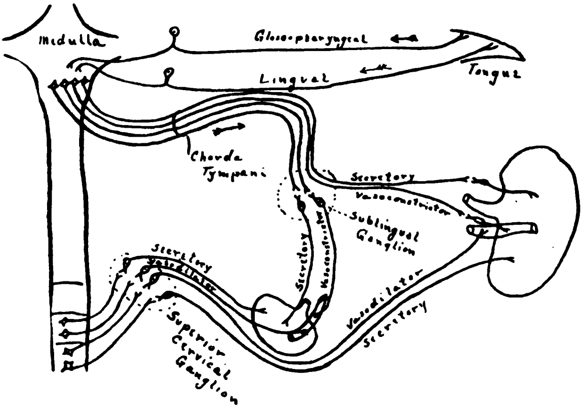

Figure XX. Nerve Supply of Salivary Glands and Reflexes regulating the secretion of Saliva.

Incoming impulses stimulate, not only secretory cells in the medulla, but, also, those of the vasomotor center which sends dilator impulses to the blood vessels of these glands by the same route as that by which the secretory fibers pass. The secretory and vasodilator fibers are cabled together by connective tissue and so form the **Chorda Tympani** branch of the seventh cranial nerve. Later, this branch travels with the lingual branch of the fifth nerve for a short distance. The reflex arc just described is probably made use of in the normal secretion of saliva and it will be observed that the nerve arrangement is such that not only are the gland cells stimulated to activity but the blood vessels are also dilated. This greater blood-supply during activity is very essential, as it supplies the gland not only with more oxygen and building material, but also furnishes more water and salts which flush out the cells.

The salivary glands possess still another nervous mechanism for exciting their secretion, the spinal autonomic, although the reflex connection is still obscure. In the upper dorsal segment of the spinal cord, cell bodies are situated which send out preganglionic fibers to terminate around ganglion cells of the superior cervical ganglion. These, in turn, give off neuraxes passing to the cells of the salivary glands and their blood vessels. The fibers passing to the blood vessels are vasoconstrictor fibers.

Action.—Ptyalin, the only ferment in saliva, acts on dextrins. An alkaline solution is desirable for its activity and body temperature is preferable. Uncooked starch is not attacked by ptyalin because each starch granule is surrounded by a cellulose wall which ruptures only by cooking. Boiled starch is called amylodextrin. Ptyalin changes amylodextrin consecutively to erythrodextrin, achroö-dextrin and later to maltose. Ptyalin also has no action on mono- or disaccharides. Not all the boiled starch attacked is changed to the maltose stage, however, the completeness depending on the time consumed in mastication and the length of time it remains in the stomach before being rendered acid by the gastric juice. As soon as this occurs, ptyalin becomes inert. It was formerly believed that this acidification in the stomach occurred very quickly, but it is now known that the certain substances are changed during the absorption process. For instance, the polypeptids and peptones are rebuilt to blood- and tissue-porteins, and fatty acids and glycerine are reunited to fat globules during absorption.

THE ABSORPTION AND ASSIMILATION OF CARBOHYDRATES.

The starches, it will be recalled, have been successively broken down in their passage through the alimentary tract from their original form to dextrins, then to maltose and finally to dextrose. Small amounts of each of these substances can be absorbed from the stomach provided their concentration exceeds 5 per cent, but such absorption is insignificant in normal digestion. The greatest portion of the carbohydrates are absorbed in the small intestines in the form of dextrose. Attention should be directed to the fact that all carbohydrates are not first changed to dextrose before absorption starts. Digestion and absorption go hand in hand. In fact, the carbohydrates are more readily absorbed in weaker than in higher concentrations, so it is probable, that, as soon as some dextrose forms, it is absorbed.

Not all of the dextrose formed by digestive action is absorbed. A portion is further acted on by bacteria, which, by their fermenting enzymes, split it into still simpler compounds, such as formic and acetic acids, carbon dioxid and water and small amounts of alcohol. These substances are not normally absorbed to any extent but are useful in several ways. They are irritating and thus stimulate intestinal peristalsis. The gases formed keep the intestines distended which allows food to pass more readily and, also serves as a buffer to reduce and disseminate the force of blows. Aside from enzymes acting on dextrose, bacteria also possess those that attack cellulose. Altogether, then, it appears that these organisms, in part at least, pay for their board.

The steps by which dextrose enters the blood through the villi may be summarized as follows: 1. It enters the cells lining the villi. 2. It leaves these cells and is passed to the lymph spaces. 3. It enters the endothelial

cells of the blood capillaries. 4. I
stream and is carried by the portal
(Figure XXI.)

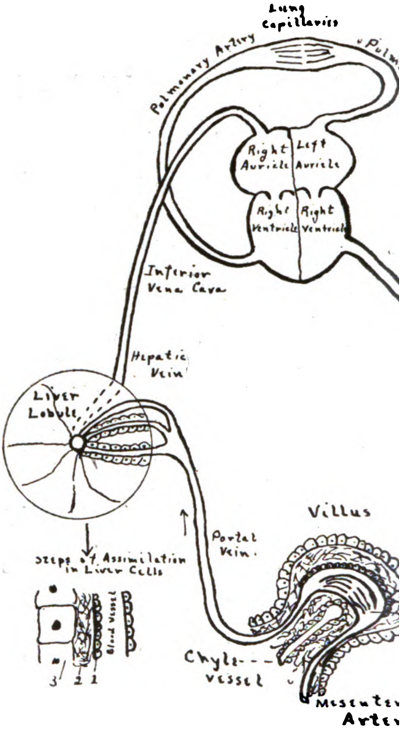

Figure XXI. Diagram showing Absorption ar

The liver is composed of small a
lobules, surrounded by connective
is made up of numerous liver cell
columns around the central vein.
sels divide and redivide, so that t
trose, comes intimately in contac
Within each lobule the blood flo
portion and is carried off by the
veins from different lobules unit
vein which carries blood from the

receive a blood supply from the hepatic artery as well as from the portal vein. The artery brings blood laden with oxygen to the liver and its capillaries join those of the portal vein inside the lobule. (Figure XXI.) Only a small portion of the dextrose is allowed to pass through the liver into the general circulation, the rest being taken up by the liver cells and stored there in starch-like granules which give a red reaction with iodine. These are called glycogen granules and are estimated to form from 2 to 4 per cent of the liver weight.

What is the object of the change of dextrose to glycogen? If all the dextrose absorbed passed through the liver, an excessive and injurious amount would enter the blood during the intervals of absorption, while between these intervals no dextrose would be supplied to the tissues. As it is, the liver cells so control the passage of dextrose that the tissues continually receive a blood laden with exactly .2 per cent, while the rest is stored as glycogen. When dextrose is no longer absorbed from the intestines, the liver cells reconvert their glycogen into dextrose so as to keep the amount in the blood constant. This function of the liver is called its **Glycogenic Function.**

The formation of glycogen and its reconversion into dextrose is either accomplished by two enzymes, one of which is capable of splitting and the other of synthesizing glycogen, or, what is more probable, is done by one enzyme with a reversable action. By this term, chemists designate the law that, when two substances react with one another in the presence of a third, the direction of the reaction depends on the relative concentrations of the first two substances. So, whether glycogen is changed to dextrose, or dextrose to glycogen by the presence of a ferment, depends on the quantity of dextrose present in the blood as compared with the amount of glycogen in the liver cells.

It has been determined experimentally that the ferment regulating this glycogenic function is secreted into the blood stream by the pancreas, for, when this organ is removed, the dextrose all passes through the liver. By studies on man and animals, it has further been ascertained that this secretion is produced by scattered groups of palely staining cells, having no ducts leading

from them, the **Areas of Langerhans.** Tl
their ferment into the blood stream an
called the **Internal Secretion of the Pan**

From the liver, the venous blood with
centage of dextrose passes by the hepati
cava to the right heart. (Figure XX
carried by the pulmonary artery througl
oxygenated, and, after returning by the
to the left heart, is pumped to all tissu
Arriving at the tissues the dextrose is
the same steps which take place in abs
of the dextrose goes to gland cells, some
etc., supplying each with fuel, in the comb
they liberate energy in its various forms
saves the proteins from being consumed
purpose and in this indirect way it is of
protoplasm. Since dextrose contains no n
not actively build protoplasm.

Having undergone combustion and yield
ashes of dextrose (carbon dioxid and wa
main. These are taken up again by the
creted, partly by the lungs, partly by the
to a smaller extent, by the sweat glands.

The combustion of dextrose is also reg
trose might be kept indefinitely in conta
oxygen than exists in the tissues and yet b
tion would occur. Another substance is
inaugurate or hasten the change, just as gu
oxygen require a spark to bring about con
our bodies a number of ferments, **Oxidases**
are able to hasten the combustion of dextr

CHAPTER XVI.

THE PHYSIOLOGICAL REQUIREMENTS OF FOODS.

To meet the needs of the body, foods must rebuild the broken-down cells and tissues as well as supply energy. The rebuilding of cell protoplasm is accomplished entirely by proteins, since they alone contain the required nitrogen. Hence, the amount of protein food taken in must at least counterbalance that broken down. If the nitrogen ingested equals that excreted the body is said to be in **Nitrogen Equilibrium.** In children the balance is in favor of nitrogen taken in, consequently the child grows. In old age the reverse process accounts for a progressive diminution in weight. During sickness or excessive labor the same holds true. Chittenden and others have shown that the ingestion of 30 to 50 grams of protein is ample to repair the cell breakdown in the normal body. Diet tables show, however, that the average American ingests from 90 to 180 grams per day, the excess being spoken of as **Luxus Consumption.** It has recently been much discussed whether such an excessive intake is desirable, for it not only throws more work on the digestive and absorbtive organs, but all the cells of the body metabolize more. Thus, if the ingestion of 50 grams of protein cause the cells of our body to destroy protein equal to 8 grams of nitrogen, then 150 grams intake requires three times the work of all the cells and the excretion of nitrogen equals 24 grams. Furthermore, the excretory organs are unnecessarily taxed in endeavoring to throw off this waste. For these reasons Chittenden and others advise the use of a protein ration just sufficient to repair the tissue breakdown. Other physiologists, while admitting that men can live on such a diet, question whether this may be considered an ideal one for the average man whose habits must of necessity be more or less irregular. They point out that natural desires have among the poor and rich alike established a higher protein intake; that those races which subsist on a low protein diet are physically inferior; that nutritional disorders charged to a luxus consumption of protein are really referable to other intemperate habits in eating and drinking and, lastly, that such diets allow no margin upon which the body may draw in the event of sudden increases in metabolism, e.g., in illness. The diet table considered as a standard by these men is that of Voit which permits 118 grams of protein per day. It may be unquestionably conceded that any intake above this is harmful.

The energy for the body functions is supplied by the metabolism of proteins in part, but most extensively by the combustion of carbohydrates and fats. The energy-giving property of a food is translated into its heat-giving value of which the **calorie** is the unit expression. A large calorie (C) is the quantity of heat required to raise the temperature of a liter of water 1 degree centigrade. One gram of protein during its metabolism yields approximately 4 C. one gram of carbohydrate the same and one gram of fat 9 calories. On this basis Voit has figured that the body requires from 2500 to 3000 calories per day to carry on normal functions and has formulated the following diet table:

	Caloric Value	Grams	Total Calories
Protein	4	118	472
Fats	9	55	485
Carbohydrates	4	500	2000
		Total	2967

The ease with which a food may be digested and ultilized for the before mentioned purposes depends 1) on its ability to start secretions, 2) on its ability to inaugurate peristalsis, and 3) its permeability to digestive juces.

Foods start secretion through chemical and psychical means. The appearance, smell and taste of food operate as much as the chemical constituents do in the alimentary tract. In order to act as an olfactory irritant, food must contain a volatile principle which reaches the upper part of the nose either during quiet breathing and sniffing or penetrates from the mouth through the posterior nares, during mastication or after swallowing.

In order to be tasted food must be soluble. Four fundamental tastes are recognized, **sweet, bitter, sour** and salty, and there is some evidence that they are conducted by different nerve fibres. Thus, sweet is tasted best on the anterior part of the tongue while sour is often only tasted on the posterior part.

The ability of foods to start peristalsis depends partly on the presence of a residue of undigested or indigestable food and partly on the presence in the food of irritating chemical substances. Not all the food ingested is utilized in the digestive tract. The residue ejected as fecal material results a) from the excessive intake of one kind of food, b) imperfectly prepared and masticated food, c) indigestable food as cellulose, seeds, fibers, etc., and d) excretory products thrown by the bile into the alimentary tract. Animal foods usually leave a small residue (5 to 7%) while vegetables leave from 75 to 90% residue. Many vegetables and fruits contain in addition laxative salts such as tartrates, malates and citrates which attract water by osmosis, and other chemical irritants which act as laxatives. Rhubarb, prunes, figs, greens, etc., may be mentioned as examples. Other plants (e.g., tea, blackberries, etc.) contain astringent principles as tannic acid and these tend to precipitate the mucin on the intestinal mucosa, preventing the ordinary irritants from stimulating intesinal movements, and they are therefore regarded as constipating substances. The permeability of the food to the digestive juices depends on the structure of the food itself, its preparation and mastication.

The density of foods varies markedly. Meats such as sweetbreads, liver, brain, fish, oysters and clams are less dense than the muscular parts of warm blooded animals. Veal and pork have a denser structure than beef. Young beef is more permeable than old. The density of cheese, heavy puddings and dumplings contrast markedly with aerated products as bread, biscuits, cake, etc. Many vegetables, fruits and nuts, eaten raw, are practically impregnable to digestive juices on account of the skins, shells, etc. surrounding them.

Cooking markedly modifies the permeability of food. In meats the connective tissue is gelatinized and the muscle fibers thus separated.

The method of cooking meat has much influence on its permeability. Meat may be either boiled, roasted

or fried. There are two ways of boilin
to start with cold water and heat gra
process the flavors, extracts and juice
part, leave the meat before it boils and
is left behind. This process is a good
one wishes the tasty substances to be in
soups and stews. The other method of
culated to retain the juices within the
case, the meat is placed in boiling wate
diately coagulates the outer layer of pro
ing back the juices. Meat prepared in th
appetizing. Roasts should also be starte
so as to coagulate the outer layer and
The roasting should then proceed with a
possible so as to prevent the whole meat
hard and dry. The gravy, as well as the
is rich in stimulating substances, some
been chemically altered by the heat.
meats are much more stimulating to the d
they are themselves less permeable since
tween the muscle cells have not been gela
are by boiling. Frying is the most unsati
od of preparing meats. Exposed to the c
temperature, meats become hard and den
fore difficult to permeate. At the same ti
lating juices have generally run out or h
dered inert by the high temperature. In
small amount of fat commonly used in fry
up into irritating substances by the heat, a
the meat. The only way to fry meats so
moderately well digested is to place the me
fat that it is entirely covered. Thus, the ou
evenly coagulated and the juices are held
which in this case does not become super-
procedure however, is not applicable to a
of meats.

It may be ascertained from the forego
permeability of meat depends to a great
preparation, but it also depends on the speci
its age and the part from which the meat i
plants, cooking ruptures the cellulose wall,
dissolves the starch granules making them
sible to the digestive juices.

Mastication determines in a final step the degree of permeability and the extent of mastication should always bear an inverse ratio to the density and "doneness" of the food ingested.

Mankind has instinctively drawn upon a wide range of food products for no single one supplies all the physiological requirements. It is next in order to examine a number of the more common articles of diet and determine to what extent each contributes to the total requirements.

Eggs: An average sized hen's egg contains about 7 grams of protein and 4.5 grams of fat. Seventeen eggs would be required to maintain nitrogen equilibrium on eggs alone while 43 would be necessary to produce a sufficient number of calories of heat. When soft boiled, eggs are easily digested, but when hard boiled only moderately well for the egg albumen can only be imperfectly penetrated, in this case. The use of condiments such as salt, pepper, mustard, etc., with boiled eggs supplies stimuli for evoking the secretions.

Milk: Milk is the secretion of the mammary gland and for general usage is derived from the cow. As sold in commerce it is usually acid in reaction. Cow's milk contains about 85% of water, 3.3% of protein, 4% of fats and 5% of carbohydrate. (See Chapter XIX, p ..). Milk contains not only all the essentials of a physiological diet, but contains them in the most digestible form. It is practically the only food used in infancy and an adult can sustain life on two quarts of milk per day. In large quantities, milk is slow to digest, however, because a dense impenatrable curd is formed by the action of rennet. For invalids milk is therefore often diluted with lime water to prevent the formation of so solid a curd, or the curdling is made to occur before drinking. This is done by the use of junket tablets (rennin) or addition of lactic acid producing bacilli to the milk. Boiling reduces the digestibility of milk, since by this process the simple proteins are coagulated and casein is made more impregnable to pepsin and trypsin. Woman's milk differs in composition from cow's milk in its lower protein and higher carbohydrate content. Rennin precipitates its casein in fine flocules and the fat globules are in finer emulsion. Mother's milk is the ideal infant food. In order to utilize cow's milk in infant feeding it is necessary to modify it by the addition of lime water and milk sugar.

Artificial Milks: These differ from each other quantitatively but all differ from milk in that they contain very little fat and too high a percentage of carbohydrate and protein. In many samples the carbohydrate is not lactose but dextrin, starch or maltose. They are extremely expensive foods and without milk fail to supply the proper nutrition and used with milk are unnecessary.

Cream: Cream may be regarded as a concentrated milk as regards it fat content, which should average 14-18.5%. It supplies the best form of fat because it is emulsified and can be digested in the stomach. Its protein and carbohydrate composition resembles that of milk.

Buttermilk: Buttermilk contains about 3% of protein, 0.5% of fat and 4.8% of carbohydrate. It is readily digested since it is not coagulated in the stomach.

Butter: Butter is composed chiefly of the fats of milk (85 to 90%) but also contains small amounts of casein and lactose. Water is present to the extent of 10 per cent and from 3 to 5% of salt is commonly added. Butter stimulates secretions by its flavors and is a most valuable energy-giving food. It leaves no residue when digested.

Cheese: The chief elements of cheese are fats and calcium paracesein formed by the artificial curding of whole or skimmed milk by rennin. This curd is compressed and otherwise manipulated. Cheese has considerable residual nutrient value but on account of its dense character it is difficult for the digestive juices to penetrate. It should therefore be eaten only in small quantities.

Meats contain from 16 to 25% of protein and a quantity of fat varying from 7 to 28%. Veal and mutten are usually leaner than beef and pork. Meats supply a large per cent of protein food while the fats eaten with them yield considerable energy. Some animal foods, as liver, contain also a fair percentage of carbohydrates. Meats, when well prepared, supply many extractives which excite the digestive juices and are themselves well penetrated by them. They are thoroughly utilized and leave little residue when they reach the large intestine.

Fowls contain about 20% of protein which exists as short muscle fibers which separate well in cooking. This is particularly true of white meat. They are readily attacked by the digestive juices. The fat content varies markedly, chicken and turkeys contrasting with geese and ducks in this respect.

As a rule smoked meats are less digestible than fresh, but pork is an exception to the rule. Smoked ham and bacon excite secretions well and are readily acted on by them. Fish and oysters are easily digested. The latter contain a large percentage of digestible carbohydrates and are useful as energy-giving foods.

Gelatin: Gelatin, which is obtained by boiling connective tissue and bones, is a favorite article of diet. It is an albuminoid, i.e., it resembles the protein molecule in composition, in many of its reactions and in its digeston. It, however, lacks two of the protein radicals (Tryptophan and Tyrosin). For this reason, gelatin cannot supplant proteins in rebuilding the body protoplasm, for, apparently these building-stones of the protein molecule are essential for its reconstruction. Animals in whose diet gelatin is entirely substituted for proteins, die of starvation.

When digested, gelatin is absorbed and takes the place of carbobydrates and fats as an energy-giving food. Hence it may be substituted for them in cases in which carbohydrates are not well borne. Like carbohydrates and fats, it is able to spare the proteins of the body from undergoing oxidation. In fact it is better adapted to this role than carbohydrates. It has been found that more than one-half of the protein may be substituted by gelatin without causing any change in nitrogen equilibrium.

Vegetable foods vary more markedly than animal foods in their nutrient ability.

Of the **cereals,** oatmeal is the most
it contains, in addition to carbohydrates,
age of fat and proteins. Cereals cause
lation of digestive juices and, since the
cellulose residue, they act as mechanical
intestinal muscles.

Grains are converted into flours, and
largely made into breads or allied aerated
duced through the action of yeast or ba
Such food stuffs are readily penetrated b
juices though they themselves excite but l
White, graham and rye bread are almost
tive value. The first leaves a residue of 3
latter two leave a residue of 60 to 65%.

Legumens (peas and beams) contain the
content of all vegetable substances (24%)
teins, however, do not compare favorabl
proteins as tissue-building material. In t
they are often contained within cellulose
less thoroughly soaked and boiled, remain
the digestive juices. Again, plant protein
down into many building stones which the
is unable to utilize in reconstructing its tis
so that a great waste occurs.

Of **roots and tubers,** potatoes form the
article of diet. They contain little protein
amount of carbohydrates. They leave a
residue. Beets contain a relatively larger p
carbohydrate. Carrots, turnips, parsnips, ra
possess practically no nutritive value but
dietary accessaries for they leave a consider
(80 to 90%) and serve to stimulate the dige
by their flavors. The same may be said of
tables such as cabbage, spinach, lettuce, celer
and asparagus. Pumpkins and squash are sl
nutritive.

Fruits are eaten largely for their flavors w
chemical and psychical stimuli to the digest
They contain very little protein and almost
a considerable quantity of carbohydrates. A
tion, they leave a residue of 50 to 80%, and
addition many chemical stimuli inaugurating

Many dried fruits, such as figs, dates, raisins and prunes are highly nutritious possessing a fair protein and fat content and a large percent of carbohydrate. The residue they leave is not so large as that from fresh fruits, but they contain substances of a chemical nature.

Olives and **nuts** supply a large percent of vegetable oils. Nuts contain a considerable percent of protein, which is often as large as that of meats. On account of their dense character, however, they are poorly penetrated by digestive juices. Hence, as ordinarily eaten, nuts probably supply but little nourishment and leave residue of 50%.

Some further idea of the physiological value of the more commonly eaten foods may be obtained from the condensed table which follows:

TABLE SHOWING COMPARATIVE FOOD VALUE OF COMMON ARTICLES OF DIET.

	Protein (Tissue (Building)	Fat (Energy	— Digestible Carbohydrate Yielding)	Residue Ability to start Peristalsis
Sweetbread	9-16%	9-12%	..	5%
Liver	21%	4.5%	1.6%	5%
Roast Beef	22%	28.5%	..	7%
Fried Beef	23%	20.5%	..	7%
Boiled Beef	24.5%	22.5%	..	6%
Mutton	19.5%	12.5%	..	7%
Veal	19.5%	7.0%	..	7%
Pork	16.5%	82.0%	..	7%
Ham	20.0%	22.5%	..	7%
Bacon	10.0%	65.0%	..	4%
Fowl	20.0%	1.5 to 30%	..	4%
Fish	20.0%	.5 to 6.5%	..	4%
Oysters	7%	1%	4.5	4%
Gelatin		100%	..	0
Eggs	14.5%	10.5%	..	0
Milk (Cow's)	3.3%	4.0%	5.0%	5%
Cream	2.5%	18.5%	4.5%	5%
Buttermilk	3.0%	0.5%	4.8%	5%
Butter	1.0%	85%	..	5%
Cheese	5%	58%	2.2%	?
Rice	8%	4.3%	79%	50%
Hominy	8.5%	6%	78%	50%
Oatmeal	16%	7.2%	67.5%	50%
Rye Bread	9.6%	.6%	49%	65%
Graham read	8.9%	1.8%	51%	60%
White Bread	9.2%	1.3%	52.5%	30%
Peas (dry)	24%	1.5%	55%	50%
Beans (green)	7%	.5%	55%	40%
Carrots Turnips Radishes Parsnips	.4%	.2%	6-8%	85%
Potatoes	1.3%	.1%	20%	40%
Beets	1.6%	.2%	80%	30%
Cabbage Greens Lettuce, etc.	1.0%	.1%	2.5%	90%
Tomatoes Asparagus	1%	.2%	2.5-8%	80%
Apples	4%	.5%	12.2%	70%
Bananas	1.3%	.6%	21%	50-80%
Oranges	.8%	.2%	15%	50-80%
Peaches	.7%	.1%	5.8%	50-80%
Pears	.3%	.5%	11.4%	50-80%
Watermelons	.2%	.2%	6.7%	50-80%
Dates	2.1%	2.8%	78%	40%
Figs	4.3%	3%	74%	40%
Prunes	2.1%	....	73%	40%
Raisins	2.6%	3.3%	76%	40%
Olives	1.1%	27.6%	11.6%	50%
Cocoanut	6.3%	57.4%	31.5%	50%
Peanut	25.8%	38.6%	22%	50%
Walnut	27.5%	63.4%	13.5%	50%

Other Factors in Nutrition: Given practically the same diet, that is, the same protein allowance and caloric value in foods, individuals differ in their state of nutrition. Some maintain only shriveled or emaciated skeletons on the same food by which others sustain a condition of nourishment varying from evenly filled out bodies to the "bay window" type of obesity. Evidently, other factors than the food supply enter into the nourishment of the body. Thinness or fatness often runs in families. In lower forms of life, small forms of cells give rise.to small ones. So there seems to be a hereditary tendency, modified frequently by environment, which influences nutrition. Age is another important factor in nutrition Cabot divides the nutritive life into three periods, Growth, Filling out, and Atrophy of Old Age. During the first epoch, the cells utilize the excess material to increase their number and size. In the second, the cells no longer use all the energy-giving food and it is stored as fat. In the third, this is lost. Loss of sleep causes a decrease in body weight, for a period of lowered irritability, such as sleep supplies, is essential in order that the cells shall economize energy. Excessive nervous strain or excitement also cause an increased consumption of energy-producing foods, leaving none for storing. Exercise may operate to increase or decrease body weight. The burning of stored fat during exercise diminishes weight, but the stimulation of the muscular tissues tends to increase their bulk later and so causes an increase again.

CHAPTER XVII.

THE GLANDS OF INTERNAL SECRETION.

There are a number of glands of the body which discharge their products directly into the blood stream and through them exert a marked influence over body nutrition. They are designated as the glands of internal secretion.

Pancreas: The internal secretion of this organ is elaborated by the cells in the Areas of Langerhans. Its nature remains undertermined. If the pancreas is removed or if these islands are affected by disease, marked nutritional derangements follow. Dextrose appears in large amounts in the blood and urine (glycemia and glycosuria). This high sugar content exerts a great osmotic attraction for water so that the quantity of urine becomes enormously increased. Great weakness and emaciation follow the excretion of so much energy containing material before it has had time to be oxidized and to liberate its energy. The condition in man is known as **Diabetis.** In animals, the grafting of a piece of pancreas under the skin may cause a complete disappearance of these symptoms or at least delay death. The pancreas then clearly exerts an important influence over carbohydrate metabolism.

Thyroid Gland: The thyroid gland elaborates a thick, colloidal secretion rich in iodine. It has been named both thyroiodin and iodothyrin. Removal of the glands in infancy or a deficiency at birth exerts a profound effect on growth and development. The child remains small and dwarf-like. It is mentally dull. The skin is bloated and puffy, while the head appears proportionally large. Such individuals are called **Cretins.** Removal of the thyroids after puberty usually causes slight changes or none, but occasionally brings on a state of chronic malnutrition, bloating and weakness called **Myxedema.** Feeding thyroid glands, fresh or dried, tends to prevent these symptoms and brings the individual back to normal again.

Oversecretion of the thyroid may also occur as in certain forms of goiter. The heart and central nervous system are then unduly stimulated causing extreme cardiac palpitation, nervousness and emaciation.

Parathyroid Bodies: The function of these glands has until recently been confused with that of the thyroids. Though situated in close proximity and often imbedded in the thyroid tissue, they have, nevertheless, distinct functions. Their removal, either early in life or after mature years, causes tremors, convulsions and tetanus, resulting in prompt death. Transplantation of the gland and injection of its extract have so far not prevented a fatal termination, though the convulsions seem to be prevented. This fact had led some to assume that the parathyroid glands do not elaborate any internal secretion at all, but serve to neutralize toxic products of metabolism.

Adrenal Glands: The adrenal bodies situated above the kidneys, elaborate, in their cortex, a hormone, variously called epinephrin, adrenalin, suprarenalin, etc. This substance exerts a marked stimulating influence on the heart and blood-vessels. Whether this substance is the same as that which influences metabolism remains doubtful.

Removal of the adrenal glands causes prompt death after symptoms of great weakness, prostration and vascular relaxation. The injection of adrenalin in such cases has met with no recovery, though transplantation of the gland has been partially successful in combating the symptoms.

Pituitary Gland: The pituitary gland, situated at the base of the brain, is composed of an anterior and a posterior lobe which differ in their functions. From the posterior or infundibular portion, a substance has been extracted in crude form which resembles adrenalin in its vascular effects. Complete removal of these posterior portions is, however, followed by neither symptoms nor death.

Removal of the anterior lobes induces a comatose or profound lethargic state. The pulse and respiration become weak and death follows. Feeding of the gland

does not prevent these symptoms, though t
of the gland prevents death. Partial ren
life or a congenital deficiency causes a g
eous deposit of fat and preserves the infan
istics. In adult life, decreased function of
also causes a partial reversion to infantile c
especially, as far as the sexual apparatus i

An oversecretion causes in early life,
the entire skeleton resulting in the devel
giant. In adult life, the extreminities al
enlargement as a result of such an increa
This condition is termed **Acromegaly.**

Sexual Glands: The ovaries and testes m
tion to being reproductive organs, be l
glands of internal secretion. Their remo
life induces characteristics of the opposite s
tion in males produces a high-pitched voic
skeleton and other female characteristics.
in young females causes the development of a
a profuse growth of hair and heavy framewor
of the sexual glands after puberty is entir
effect, however, and never causes death.

SECTION V.

THE PHYSIOLOGY OF EXCRETION.

CHAPTER XVIII.

THE LIVER AS AN EXCRETORY ORGAN.

In addition to its glycogenic function, the liver has an excretory one. The general anatomy of the liver with its lobules of liver cells supplied with blood from the portal vein and hepatic artery, has already been studied. (See Chapter XV, page 92). On the side of the liver cell opposite its contact with the blood vessels, there is an exit for the substances formed in the organ. The back door avenues are the bile capillaries. These have for their walls the liver cells themselves, but, as they increase in size and approach the hepatic duct, they acquire an epithelial lining. Connective tissue and muscular elements are also added in the larger ducts. The hepatic duct collects the secretion from the whole liver. It joins with the cystic duct coming from the gall-bladder and the two form the common bile duct which empties into the duodenum together with the pancreatic duct. The opening of the bile duct is guarded by a muscular sphincter. (Figure XXIV.)

Bile, formed from the products broug
by the blood, is secreted continuously by
As far as is known, its secretion is nc
nerves, but is increased in amount wher
flow through the liver is augmented. C
smaller bile ducts, it is at first moved on
lation of new bile behind, in other words
tory force of the cells. As it reaches th
it is pushed forward more rapidly by the
the muscular walls. Bile does not cont
the duodenum because the sphincter remai
for this reason, it backs up into the gall-
it is stored. At intervals during digestic
charged into the duodenum by a simulta
tion of the sphincter and a contraction of tl
and bile ducts. This is set up by a reflex f
ach and duodenum, afferent fibers passin
the vagi and efferent fibers passing back by
nic nerves. (Figure XXIV.)

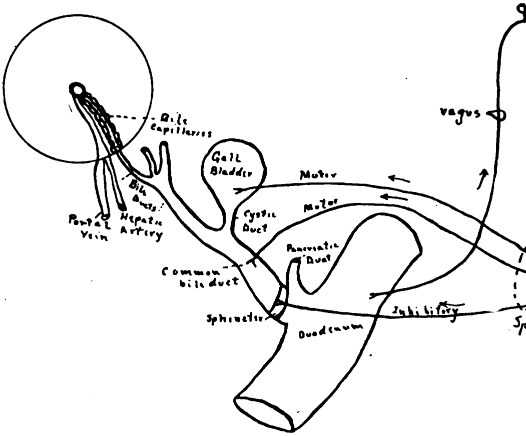

Figure XXIV. Diagram of the Biliary Tract and the Refl
Ejection of Bile.

Composition of bile: Bile is a golden yello
fluid with a specific gravity of 1.050. It co

solved in water, various alkaline salts, bile pigments (bilirubin and biliverdin), two bile acids (glycocholic and taurocholic) or their sodium salts, cholestrin, lecithin, traces of fatty acids, fats, soaps and mucin.

Source of the Bile Products.—Products of protein and carbohydrate breakdown are carried to the liver by the portal vein and the hepatic artery. The amino-acids, ammonium carbonate and ammonium carbamate are the chief elements of protein breakdown, and, as before pointed out, these are largely converted into urea. A portion, however, is changed to taurin and glycocol. Some of the carbohydrates and fats are not completely oxidized to CO_2 and H_2O, but give rise to cholic acid which is carried to the liver and, combining with taurin and glycocol, is excreted as the taurocholic and glycocolic acid of the bile.

It has already been pointed out that when the red blood cell is broken down and hemoglobin liberated, this is carried to the liver and the iron extracted. The remainder of the hemoglobin molecule is excreted as the bile pigments, bilirubin and biliverdin.

Cholestrin and lecithin are added to the bile by the cells lining the bile ducts and gall-bladder. The same may be said of mucin which gives the bile a viscid character. The salts and alkalies are secreted by the liver cells.

Functions of the Bile.—The bile, while supplying an avenue for the excretion of waste products, is not entirely a functionless secretion. Bile acids are reabsorbed to a certain extent and act as secretory stimulants to the liver cells. They hold lecithin and cholestrin in solution and thus prevent the formation of calculi. Bile is supposed to act as a feeble intestinal antiseptic, and by means of its alkalies and soaps, it aids in the emulsification of fats.

The pigments are partly reduced in the intestinal tract to hydrobilirubin which forms the normal coloring matter of the stools, and to some extent they are reabsorbed to be later excreted as coloring matter in the urine (urobilin).

CHAPTER XIX.

THE SECRETION OF URINE, M

The kidneys are the avenues by whic
ucts of metabolism leave the body. B
kidney through the renal artery which
branches so as to bring the blood into
the kidney units. A kidney unit may
posed of an invaginated ball of flat
man's capsule, and a series of comm
Those are named from their shape
following order: proximal convolute
tubules, the descending and ascending
irregular portion and a distal convolu
ing into the straight collecting tubule

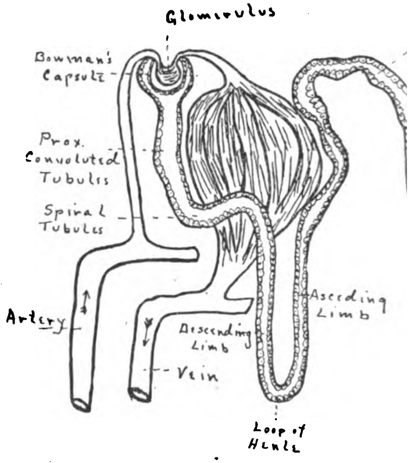

Figure XXV. Diagram of a Kidney Unit an

These tubules, in contrast to the Bo
lined with large cuboidal cells resemb
The blood supply of these kidney
Blood-vessels entering the Bowman

divide, later to come together again forming a rete mirabile. This is called the glomerulus of the kidney. These glomerular vessels leave the Malpighian corpuscle, as the whole structure is called, by a small efferent vessel which breaks up in the ordinary manner into a large network of capillaries surrounding the convoluted, spiral and irregular portions of each unit. The blood is then led away by veins following the larger arteries. It will be seen that the blood-vessels are so arranged in relation to the secreting epithelium that secretion can occur at two places, in the glomerulus and in the tubules.

Tle blood brought to the kidneys is alkaline in reaction and contains the following substances in solution: serum globulin, serum albumin, urea and uric acid, carbonates, phosphates, sulphates and chlorides of sodium, potassium and calcium, urobilin, fats, cholestrin and lechithin. The urine, on the other hand, is acid and contains salts and water with only three of the above organic constituents, urea, uric acid and urobilin. The others have not been allowed to pass through. The cells thus normally possess a power of holding back certain substances. Urine has a specific gravity of 1.020 to 1.025.

Under certain conditions, the renal cells lose their power to retain these organic substances. For example, they may become altered by drugs or infectious agents so that serum albumin and serum globulin are allowed to pass through into the urine. This condition is known as **Nephritis or Bright's Disease.** Even normally the cells are not capable of holding back more than .2% of dextrose, and, whenever the amount in the blood exceeds this limit, some of it passes into the urine, a condition called **Glycosuria.**

Physiologists are as yet not agreed as to the manner in which urine is secreted. Two main theories are held: that of Ludwig which maintains that all the constituents of urine are secreted by the glomerulus in a dilute form and reabsorbed from the lumen by the cells lining the convoluted tubules; and that of Bowman and Heidenhain which maintains that the glomerulus secretes water alone, while the organic constituents are eliminated by the convoluted tubules. It will be seen that one theory

attributes a secretory and the other a
tion to the tubular epithelium.

The quantity of urine secreted va
1200 cubic centimeters per day. Less
sleep. Secretion of urine is not regul
the quantity depends on the follo
amount of blood flowing through the
sure under which the blood is supplie
sure), the concentration in which the
(Osmosis Factor), and the activity
themselves.

THE TRANSFER OF URINE TO

Urine is continuously secreted by
carried by the contractions of the ure
The ureter is composed of nonstriate
tracts at intervals of 10 or 20 second
all nervous infleunces. The ureter op
the bladder wall that, as the tension
the bladder increases, the openings a

MICTURITION.

The bladder is emptied by the act
nervous mechanism is very similar t
In the infant, it is a simple reflex res
of the internal sphincter and contra
musculature. In the adult, increase
sensation of fullness through the sti
nerve endings, and, even though th
may tend to be relaxed, the act is v
as in defecation, and the external sp
capacity of the bladder varies from
the varying degree of tonus presen
plains why the desire to micturate m
the bladder contains but little urine.

CHAPTER XX.

THE SWEAT GLANDS IN EXCRETION.

The sweat glands are simple tubular glands distributed over the entire body, though certain localities contain a greater number than others. It is estimated that there are a total of 2,000,000 of these glands.

Sweat is a colorless liquid, having a specific gravity of 1.003 to 1.006. It is acid in reaction when first secreted. In the body at rest, sweat is evaporated as fast as formed and only exceptionally collects as a liquid upon the skin. Consequently, it is usually not realized that from 700 to 1000 cubic centimeters per day are secreted. Though sweat often more than equals the quantity of urine secreted, it contains few substances besides water. Traces of salts and still feebler traces of urea, uric acid and other organic compounds are present. Its excretory value is then evidently limited to relieving the kidney of an excessive burden of water secretion.

Nerve Control.—Experiments have shown beyond a doubt that the sweat glands are regulated by secretory nerves and that sweating results from stimulation of these nerves alone. The sweat centers are distributed widely throughout the spinal cord but are not localized into any circumscribed center. Sweating may be occasioned by stimulating the cells in the central nervous system, as happens when the temperature of the blood is increased in fevers. They may be reflexly stimulated, as happens when heat is applied to the skin. Certain drugs, as pilocarpin, cause sweating by affecting the nerve endings in the gland. Experiments have shown that sweating may go on when the blood is entirely cut off from the skin, but, obviously, a prolonged secretion could not occur under these conditions.

SECTION VI.

THE PHYSIOLOGY OF RESI

CHAPTER XXI.

EXTERNAL RESPIRAT

The oxygen necessary to burn protei
and fats is obtained from the air. It
respiration to transfer it from the air
then from the blood to the tissues.
spoken of as **external** and the second a
tion.

The organs directly concerned in ex
are the nose, larynx, bronchi and lun
and bronchi contain more or less per
tilage within their walls by which tl
tinuously kept open. This is essentia
and outflow of air. Ciliated epithelium
which, by the outward motion of the
removal of small particles inhaled wi
smaller bronchi are under the contr
mechanism similar to that of the blood-
caliber is therefore variable. The l
masses of tubules that have divided an
the large bronchi into smaller bronchi
to terminate at last in closed expanded
buli. These infundibuli, in turn, have n
the alveoli or air cells. As the divisi
progresses, the walls become thinner,
cartilage, then their muscular elemen
the air cells are lined by a single layer

The pulmonary artery, carrying veno
heart subdivides repeatedly and in such
capillaries come into intimate contact
of the lungs. Thus, only two endotheli
the blood and air.

The lungs together with the heart ar
structures are placed in the thoracic c

is surrounded by two layers of a serous membrane, the pleura. Of these, the visceral layer is attached to the lungs and the parietal lines the chest wall. The layers are everywhere in contact, nevertheless the term **pleural cavity** is applied to the potential space for physiological reasons.

In addition to the main respiratory system, the diaphragm and the muscles moving the ribs must be regarded as subsidiary organs of respiration, since they play an important part in bringing air into the lungs.

THE RESPIRATORY MOVEMENTS.

Respiration is divided into two phases, **inspiration and expiration.** On inspecton, these may be observed as rythmcal expansions of the abdomen and thorax recurring from 16 to 20 times per minute. Inspiration is slightly shorter than expiration, the ratio being 5:6.

In inspiration, the thorax is enlarged antero-posteriorly, laterally, and downward, by the action of the thoracic muscles on the ribs. The first mentioned enlargement is produced by the elevation of the ribs from their normal downward slant to a more horizontal position. As shown in Figure XXVI, when the ribs are carried from a point C to A the antero-posterior diameter AB must be greater than it was at CO. The lateral enlargement is brought about by the elevation and outward displacement of the ribs, more especially the lower ones.

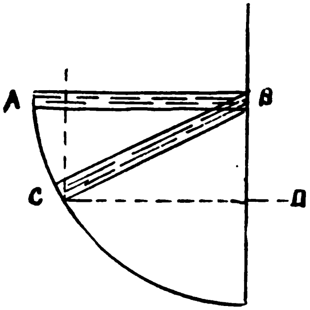

Figure XXVI.

The ribs move outward when elevated because the articular plane between them and the vertebrae is not horizontal nor does the articular surface point directly outward. The farther down the cord one looks, the more the articular surfaces point downward and backward, as well as outward. The thorax is enlarged downward by the depression of the diaphragm. This dome-shaped organ contracts, and, in so doing, compresses the abdominal viscera. From these the pressure is communicated to the abdominal walls which bulge during inspiration.

As enlargement of the thorax is under the control of muscles, we call inspiration an active process. When the muscles have reached the height of their contraction the lungs have become fully expanded and a certain elastic force has been stored in them. When muscular action ceases, there is a recoil of the lungs, which, together with the elastic dropping back of the thorax to its normal position, causes expiration. This latter phase, it will be noticed, is purely a passive act carried on without any muscular action.

THE CAUSE OF LUNG INFLATION.

In its pre-natal state the child does not breathe with its lungs, which are no more than a collapsed mass. At birth, then, the intrathoracic pressure is the same as the atmosphere, which Toricelli has shown to have a weight equal to 760 mm. of mercury. Immediately after birth, however, the child begins inspiratory movements, thus *tending* to create a space about the lungs, in which the pressure becomes less than atmospheric and is accordingly called **negative.** The formation of an actual space between the layers of pleura is prevented, however, because the outside air rushes into the lungs from a higher to a lower pressure, as it might into an expanding bellows, and inflates them to the full capacity of the thoracic cavity. In expiration of an infant, the intrapulmonic pressure again becomes the same as atmospheric and all the air within the lungs is practically removed.

	In Expiration	In Inspiration
Atmospheric pressure	760 mm	760 mm
Intra-thoracic pressure	760 mm	750 mm
Difference	0 mm	3 mm

In the adult, the intrathoracic pressure is less by 4 or 5 mm. than atmospheric (or is negative) even in expiration. This change is due to the fact that, as growth occurs, the lungs do not keep pace with the chest walls. Consequently, some air always remains in the adult lungs. As the thorax enlarges in inspiration the already negative pressure must be exerted over a large area, and hence becomes more negative. Thus a greater difference in the pressures within the thorax and outside exists during inspiration than during expiration, and air rushes in.

	In Expiration	In Inspiration
Atmospheric pressure	760 mm	760 mm
Intra-thoracic pressure	760 mm	757 mm
Difference	5 mm	8 mm

THE NERVOUS CONTROL OF RESPIRATION.

The respiratory muscles act together in a co-ordinated manner because they are regulated by a nervous mechanism, the center for which is located in the medulla. If the medulla is destroyed, respiration ceases. The center is bilaterally situated and the halves are connected by commissural fibers. If these are cut, respiration still continues but not synchronously on the two sides. The center on each side is composed of two portions, an inspiratory and an expiratory, connected by communicating fibers. From the cells situated in these centers, fibers pass down the cord to stimulate anterior horn cells at different levels of the cord. These cells, in turn, send fibers by way of the phrenic nerve to the diaphragm, and by the thoracic and cervical nerves to the intercostal and other respiratory muscles.

The inspiratory portion of the respiratory center is normally automatic, i. e., discharges impulses without being stimulated. This automatic action may, however, be influenced reflexly. The effect produced by the sight of startling phenomena or the effect of cold water suddenly applied, are well known to inhibit breathing. In addition, a voluntary control over the respiratory center exists in that both the rate and amplitude of respiration can be altered at will.

The expiratory center is normally not automatic, in fact, is not active, since normal expiration requires no muscular stimulation. It may become automatic, however, if the center is deficiently oxygenated. A forced expiration is then the result. The center may also be reflexly excited, but only by special stimuli such as give rise to sneezing, coughing, etc. A cerebral control, made use of in vomiting, defecation and micturition also exists.

CHAPTER XXII.

THE INTERCHANGE OF GASES IN THE LUNGS AND TISSUES—BODY HEAT.

Air is a mixture of nitrogen, oxygen, carbon dioxid and other gases in unessential proportions. Each gas, in accordance with the **Law of Partial Pressures,** exerts a pressure in proportion to the percentage of that gas in the mixture. Air is found by analysis to contain nitrogen 70%, oxygen 20% and carbon dioxid .04%. Since its total pressure is 760 mm. that of its gases must be as follows:

Nitrogen =79/100 of 760=600 mm
Oxygen =20/100 of 760=152 mm
Carbon dioxid =.04/100 of 760=3 mm

Such air does not actually come in contact with the blood, however, for, in the adult, only about 1/6 of the air is renewed in every inspiration. This represents a renewal of about 500 cc. called the **Tidal** air. In addition, 1600 cc. of air can be taken during a forced inspiration and a like amount can be forced out by a forced expiration. These are designated as **Complemental** and **Supplemental** air, respectively. About 1000 cc. of air cannot be displaced during the most forced expiration and this is called the **Residual** air. The total air content or **Vital capacity,** as it is called, thus equals 4700 cc. By this process of partial air renewal, alveolar air becomes a mixture of atmospheric and expired air. It is impossible to determine its exact composition, but, in indirect ways, its chief constituents have been found to have the following partial pressures, oxygen=129; CO_2=28 mm.

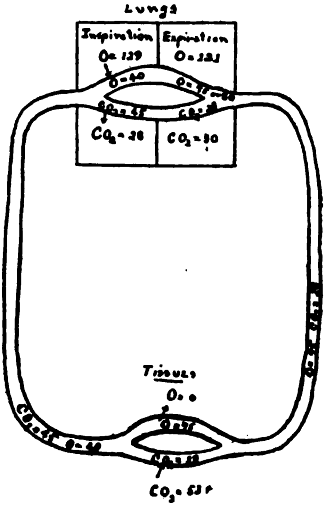

Figure XXVII. Diagram illustrating the Interchange of Gases in the Lungs and Tissues.

If a gaseous mixture with such partial pressures should be separated from another with the partial pressures, O=40 and CO_2=45 mm, then these two gases would diffuse until their partial pressures were equal. If one of the gases were dissolved in water the same result would come about. This is exactly what occurs in the lungs and tissues in respiration. (Figure XXVII.) The oxygen from the alveolar air enters the blood because the partial pressure of oxygen is less here (40) than in the alveoli (129). The oxygen saturates the plasma up to 25% and the remainder combines loosely with hemoglobin. The oxygenated blood is distributed to the tissues. The oxygen is removed from the plasma through the capillaries because the partial pressure is lower in the tissues (0) than it is in the blood (75). Carbon dioxide, on the other hand, passes from the tissues to the blood because the pressure in the tissues is higher (53) than in the blood (28). It combines partly with salts of the blood to form carbonates, partly with albumins and remains partly in solution. The blood thus laden with

CO_2 returns to the lungs where CO_2 diffuses out to the lower pressure in the alveoli.

COMBUSTION AND BODY HEAT.

So far, oxygen has been traced to the tissues. It is necessary also to understand how it is used there. Attention has been called to the fact that cells utilize oxygen in order to liberate energy during their metabolism and that one form of energy is heat. The temperature of man is normally 98.6° F. regardless of external temperature. The heat of the body depends, not only on the heat generated but also on the amount dissipated. The amount of heat generated by combustion can be regulated by the kind of food ingested; e. g., fats which yield much energy are freely used in cold climates.

Heat is dissipated (1) by the excretions, feces and urine; (2) in expired air both through warming it and by vaporizing water; (3) by evaporation of sweat from the skin and (4) by radiation and conduction from the body. The last factor is regulated by the vasomotor nerves of the skin. When body temperature rises above normal a thermal stimulus causes them to dilate the blood vessels, thus bringing a greater supply of blood to the skin for cooling. The respiratory center is also stimulated when the body becomes overheated, and, as a result, respiration becomes accelerated. If, on the other hand, the body temperature falls below normal, the skin vessels constrict and keep the blood away from the cooler exterior.

SECTION VII.

THE PHYSIOLOGY OF THE CIRC

CHAPTER XXIII.

THE CIRCULATORY ORG

The circulatory system is composed o
teries, capillaries, and veins. It is divided i
circuits, the pulmonary and systemic.
the blood is carried from the right side
the lungs and, after passing through the
to the left side of the heart. By the sys
is carried from the left heart through all
of the body back to the right side of th

The heart may be regarded as a musc
sisting of two auricles and two ventricl
right and left. The two sides of the
rythmically together, the sequence bei
then ventricles. Guarding the openin
auricles and ventricles, are valves, the n
side, the tricuspid on the right. The mo
and pulmonary artery are also guarded
called the semilunar valves. The arte
heart branch into smaller ones and eve
arterioles and capillaries. Lining the en
tem from the heart to the capillaries
layer of endothelial cells. These cells
surface which minimizes the friction of
form the only wall of the capillaries a
ness, favor the passing of oxygen and n
to the tissues, at the same time that th
blood corpuscles. Beginning in the arte
progressively heavier as the arteries ar
find, outside of this endothelial layer,
elastic fibers which prevents their coll
and by their elasticity permits their a
varying quantities of blood. In these

also found muscle fibers, arranged in circular fashion so that, by their contraction they are able to diminish and, by their relaxation, to increase the size of the vessels. They are few in number in the large arteries, but much more numerous as the arterioles are approached. It is in the arteriole area that the vasomotor nerves perform their most important function, viz., that of regulating the amount of blood leaving the arterial side, as well as increasing or diminishing the friction. A certain amount of friction always exists between the blood stream and the vessels and this increases as the caliber of the vessels diminishes. Without a certain amount of constriction in the arterioles, however, there would not be enough friction to maintain a normal circulation.

The ventricles, arteries, arterioles and capillaries form the **distributive portion** of the vascular system, i. e., they carry food and oxygen to the tissues. The venules, veins and auricles form the **collecting portion.** The vessels comprising the collecting portion are much thinner than the corresponding ones of the distributive portion.

Blood is sent on its way to the tissues by the contraction or **Systole** of the ventricles. The ventricles when filled go into systole, and, in so doing, close the mitral valves, thus preventing regurgitation into the auricles. At almost the same time, the semilunar valves are opened allowing blood to pass into the aorta and pulmonary artery. This ejection occurs more swiftly at the earlier than at the latter part of systole. As the ventricles relax, or go into **Diastole,** the semilunar valves close and so prevent a backflow from the large vessels into the heart. The mitral valves simultaneously open and the ventricle is refilled from the collecting system. This filling occurs in the following manner: During systole of the ventricle blood has accumulated in the large veins and auricles, and, consequently, the pressure there has increased. When the ventricle relaxes a negative pressure is created within it which sucks the blood from the auricle into the ventricle with great rapidity. (Figure XL.) About 8/10 of the entire filling is thus accomplished in the early part of ventricular diastole. This is followed by a period when no or very little blood passes into the ventricle, a period designated as **Diastasis** of the ventricle by Henderson. Later, the auricle contracts

and contributes about 1/10 to 2/10 t
of the ventricle.

SUMMARY.

1. **Circulatory System divided into**
   - **a) Pulmonary Circuit**
     - Distributive Portion
       - Right ventricle
       - Pulmonary artery and bran
     - Collective Portion
       - Capillaries
       - Pulmonary vein and tribut
       - Left auricles
   - **b) Systematic Circuit**
     - Distributive Portion
       - Left ventricle
       - Aorta and branches
       - Arteries and capillaries
     - Collective Portion
       - Venules and veins
       - Right auricle
2. **Layers of Blood Vessels and thei**
   - a) Endothelial layer
     - Minimizes friction
     - Permits interchange of substa
   - b) Elastic Fibers
     - Prevent collapse of empty ar
     - Permit accommodation of mo
   - c) Muscle Fibers
     - Actively vary caliber and resis
     - Supply elasticity.
3. **Filling of Ventricles during Dias**
   - a) Suction of ventricle
     - Accumulation of blood in cause 8/10 of ventricular
   - b) Period of Diastasis or no fillin
   - 3) Contraction of auricle—Contri filling.
4. **Events happening during Systole**
   - a) Auriculo-ventricular valves clo
   - b) Semilunar valves open
   - c) Blood ejected into aorta by contraction.

CHAPTER XXIV.

BLOOD PRESSURE.

With each ventricular systole about two to four ounces of blood are forced into the aorta. This discharge is very rapid, taking about .2 of a second. The blood entering the aorta finds it already filled. Room is made, partly by pushing the column along, and, partly by stretching the elastic walls of the arteries. A finger placed over the artery feels it grow tense with every heart beat, in other words, it detects the **Pulse.**

The mechanical energy expended by the heart in forcing out the blood is changed partly into kinetic energy (energy of flow and motion), and partly into potential energy (used in stretching the walls). Acting in accordance with a physical law, if the blood exerts a tension on the arterial wall and stretches it, the wall will exert an equal return pressure on the blood. This is **Blood Pressure,** and can be determined in various ways.

If an artery is cut, the blood spurts out for some distance, while from a cut vein it flows slowly, showing that the pressure is much lower in the latter case.

If an artery is connected with a long vertical tube, its pressure is measured by the height to which blood rises in the tube. It will be found, on such a procedure, that the arterial blood pressure is not constant, but rises with each systole and falls with each diastole. If such a tube is connected with a vein, the blood rises only a few centimeters and no oscillations are present. We may therefore state that the arterial pressure is high and oscillating, the venous pressure low and constant.

The readiness with which blood coagulates in the tubes, however, prevents any extended use of this method of studying blood pressure. For this reason, a mercury manometer connected with the artery by a tube of anticoagulation fluid, is used. This instrument consists of a U-tube partly filled with mercury, in one arm of which a float rises and falls with the mercury, and, in so doing, writes with a pointer on the drum. (Figure XXIX

A.M.) The difference between the height of the mercury in the two limbs expresses the blood pressure in mm. of mercury. By these and similar methods, it has been determined that the arterial pressure of a dog is about 120 mm. of mercury, the capillary pressure 20 to 40 mm. and the venous pressure about 4 to 13 mm., meaning that the mercury in a manometer was displaced that distance.

If a curve from the carotid artery is written on a smoked drum, three kinds of rythmical variation above and below the 120 mm. level will be seen; 1) the smallest or **cardiac waves**; 2) the larger or **respiratory waves**, and 3) the very long **vasomotor waves.** (Figure XXVIII)

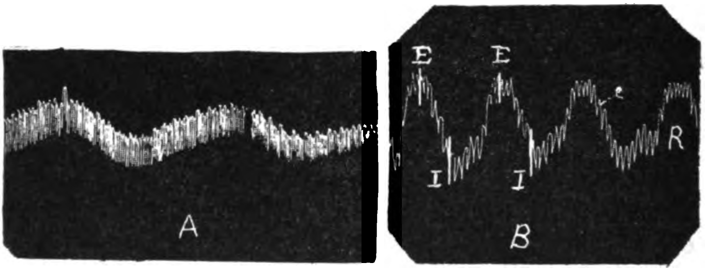

Figure XXVIII. A, Vasomotor Waves of bglood pressure recorded on slowly moving drum. B, Respiratory waves (R) and cardiac waves (C) of blood pressure recorded on more rapid drum. I, inspiration; E, expiration.

The cardiac waves are due to the ventricular systole and diastole. The pressure rises during systole because the blood pumped in distends the arterial wall, thus storing potential energy or pressure. It falls during diastole because, during that period, the elastic walls recoil and the fluid is smoothly pushed through the capillaries and veins. This explains why the flow continues in the veins during diastole, as well as during systole.

As blood pressure always means a distension of the vessel walls, and, as this can be accomplished only by the presence of fluid, it follows that blood pressure depends 1) on the amount of fluid injected during each systole of the ventricle, the **pulse volume**; 2) on the rate of this injection, and 3) on the extent to which the peripheral constriction prevents fluid from running out. Resistance is offered to the outflow of blood from the arteries by all the vessels but mostly by the capillaries. This resistance is constant and unchangeable. The area able to change its caliber by muscular action is the arteriole area.

The factors which determine blood pressure may be studied by means of an artificial circulation apparatus. (Figure XXIX.) Such an apparatus consists of a reservoir representing the auricle, a compressible bulb representing the ventricle, a system of elastic tubing controlled by a screw clamp representing the arteries and arterioles, a tube of firmly packed glass wool representing the capillaries and a second system of tubes representing the veins.

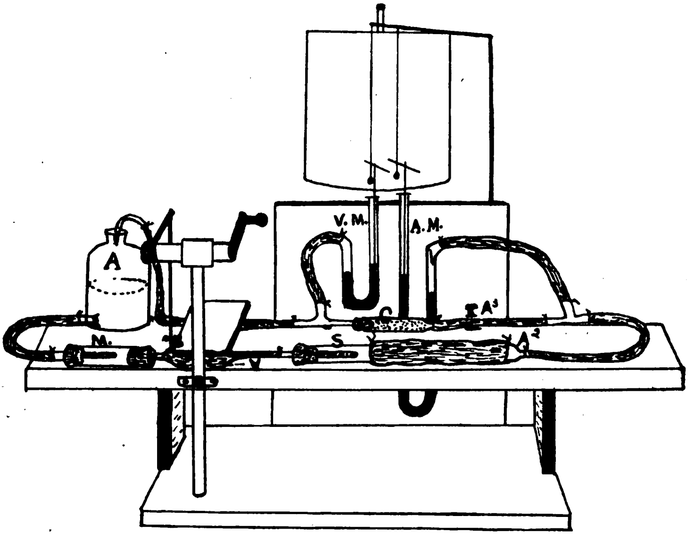

Figure XXIX. Artificial Circulation Apparatus. (Used at the Physiological Laboratory of the University of Michigan.) A, auricle; M, mitral valve; V, ventricle; A², large arteries; A³, arterioles; C, capillaries; V. M., venous manometer; A. M., arterial manometer.

If the pressure from the arteries and veins are recorded on a revolving drum by two mercury manometers (Figure XXIX), a curve showing a systolic rise and a diastolic fall in the arterial pressure is obtained. (Figure XXX.) The venous pressure remains low and shows

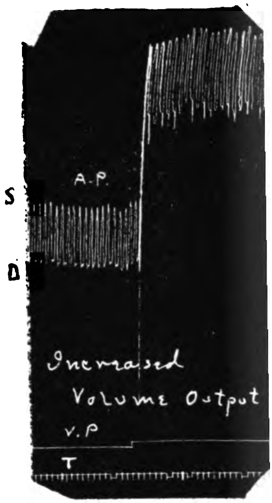

Figure XXX. Record taken with Artificial Circ
Arterial Pressure; V. P. Venous Pressure.
of increasing Output of Ventricle.

no oscillations. If now the compres
increased, the arterial as well as the
rise. If the compression is made
tend to fall, showing, in each case,
the ventricle determines the height o
If the rate of compression is increase
in the arterial and venous blood pre
(Figure XXXI), showing clearly t
heart is a second factor in determini

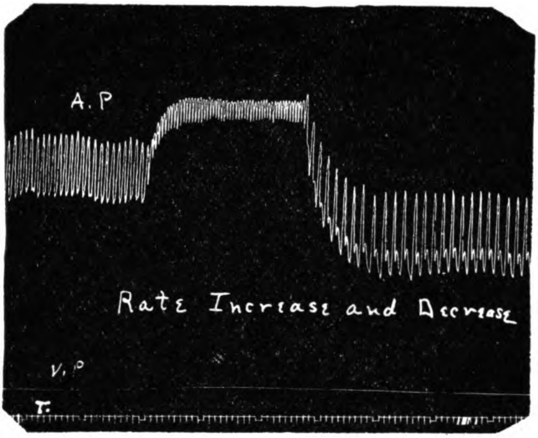

Figure XXXI. Lettering same as preceding. Effect of Changing the Heart Rate on Blood Pressure.

If the screw clamp representing the constantly constricted arterioles is now loosened, the arterial pressure becomes much lower, but the venous pressure becomes higher and variable. A gradual tightening of the screw clamp causes a gradual rise in arterial pressure and a fall in venous pressure together with an obliteration of the venous oscillations. (Figure XXXII.) Evidently the peripheral resistance of the arterioles influences arterial and venous pressures in opposite directions.

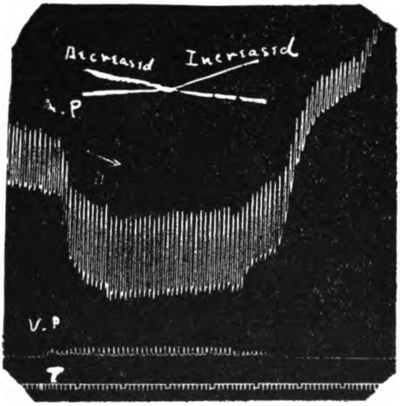

Figure XXXII. Lettering same as before. Effect of Decreasing or Increasing the arteriole construction by a screw clamp.

In the body, the arterioles underg tions in caliber and thus regularly dec the arterial pressure, as shown in the l pressure records. These waves are ca waves. (Figure XXVIII A.)

The third kind of waves found in t ords are the respiratory. As shown in the pressure at first slightly falls but spiration, while in expiration it first then falls.

The thorax is a closed box. Enterin communicating with the lungs, and t arteries communicating with the hear ment of the thorax during inspiratic sucked into the lungs, but blood is heart. Thus, in inspiration, more blo from the veins. If the heart receives pump more during each beat, a fac learned would raise blood pressure. increases during inspiration and aid pressure rise. During expiration bl sucked into the thorax and the heart than in inspiration. This allows less to pump out each beat, and this fac slowing of the heart rate causes t This explains why the pressure mai tion and mainly falls in expiration. remains, "Why does the pressure co beginning of inspiration and continue ning of expiration." In answer to the that the vessels of the lung must first a greater amount of blood reaches t inspiration. The answer to the seco distended lung vessels again collapse this for a short time causes the left plied with an extra amount of blood of expiration.

THE FLOW OF BL

It is a physical fact that the rate stream is greater than in a wide one.

progressively smaller, one might imagine that, as the periphery is approached, the flow of blood becomes more rapid and again slower in the veins. The truth is, however, that the flow becomes slower as the capillaries are approached and more rapid again in the veins. Thus the rate of flow in the arteries is about 260 mm. per second, in the capillaries only 5 to 9 mm. but in the veins again it is about 225 mm. This result is due to the fact before pointed out that the total stream bed actually increases as the vessels branch more and more, the combined capillary area being calculated to be about 800 times as wide as that of the aorta.

The time necessary for a corpuscle to make a complete circuit of the blood is about 23 seconds, of which one-fifth is spent in the pulmonary circuit.

The blood is not a simple fluid, but contains solid cells. It may be likened to a stream full of fish, which would be passively moved on by the current, impeded by obstacles, often colliding with one another and bending and twisting on turning corners. The blood stream may be conveniently studied by observing the circulation in the web of a frog's foot through a microscope. It will be seen that the flow in the arteries is intermittent and very rapid. The corpuscles are everywhere so densely packed together that their outlines are obscured. Towards the center they appear even more closely packed than at the periphery of the vessel. This dense central stream, spoken of as the **Axial Stream,** has a much greater speed than the so-called **Inert Layer** on the outside. This is due to the friction with the vessel wall at the periphery.

Through the capillaries, the red blood corpuscles can be seen to pass in single file at a slow pace. Here they give the appearance of so many oval coins floating on edge or on their flat sides. At times they appear larger than the capillaries through which they pass and must be distorted to squeeze through. This is possible because of their elasticity. In the veins, the flow is again more steady. The corpuscles are not so closely packed as in the arteries, therefore, their outline here is more distinct. There is no such demarcation between axial and inert layers.

SUMMARY.

Blood Ejected During Ventricular Systol

a) pushes fluid ahead, creating en
Energy)

b) distends elastic arteries creati
(Potential Energy)

lood Pressure Depends,

a) on rate of cardiac discharge

b) on volume of blood pumped p

c) on degree of constriction in p

Blood Pressure Variations.

a) Cardiac waves—rise in systol
ventricle.

b) Vasomotor waves—rise whe
fall when they relax.

c) Respiratory waves—rise chie
chiefly in expiration.

Blood Flow.

a) In arteries—Intermittent stre
packed, outlines indistinc
has more speed than i
vessel.

b) In capillaries—Red blood co
file, stream steady but

c) In veins—Stream steady and
illaries, corpuscles disti
into layers in the stream

CHAPTER XXV.

THE HEART AND ITS MOVEMENTS.

Anatomy.—The heart is an irregular, cone-shaped, muscular organ composed of right and left auricles and ventricles. These chambers, however, do not occupy absolutely right and left positions in the adult heart as their nomenclature indicates. (Figure XXXIII.) The right auricle and ventricle form largely the right and anterior portions of the heart, while the left auricle and ventricle make up the left posterior portion, forming only a small part of the anterior surface. The apex consists entirely of the left ventricle. The base is almost completely made up of the auricles and the openings of the large veins into them. Viewed from behind (Figure XXXIV), we see to the right the openings of the inferior vena cava, below, that of the superior vena cava above, while to the left are seen the pulmonary veins entering the left auricle. If the auricles are removed and we look down upon the heart, we see the bases of the ventricles and the arteries. The opening of the pulmonary artery is most

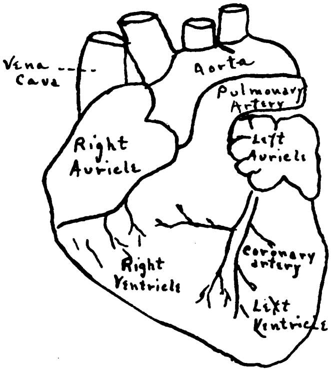

Figure XXXIII. The Heart (Ventral Aspect).

anterior. Behind this is the opening
communications between the auricles
still more posterior and are guarded b
Viewed from the front (Figure X
monary artery is seen to be given off f
tricle and then to pass over to the lef
arising from the left side, behind and
pulmonary orifice, passes beneath this
side.

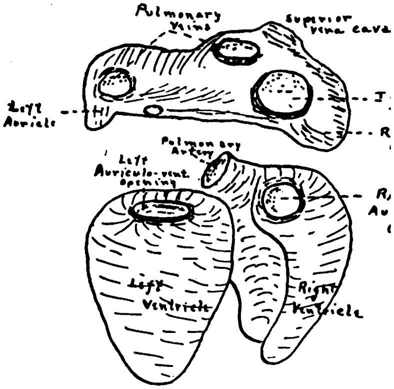

Figure XXXIV. The Heart Dissected (F

While all the muscular fibers of th
tinuous net works, the different ch
sected apart, as shown in Figure
way, their shape and the thickness
walls can be studied. The musculat
tricle is far heavier than that of th
turn, much more heavy than that c
auricles. The left ventricle forms
over the right side of which the conc
ventricle fits. The auricles cap the
tricles. The cavity of the relaxed lef
a cone and in cross-section is round
relaxed right ventricle, on the other
flattened and indented cone and in c
semilunar.

The heart is situated within the p
composed of two smooth serous su

epicardium, being closely connected with the heart muscle, the outer forming a sac in which the heart is suspended. The external layer is attached to the internal only around the large vessels at the base of the heart where it is also very slightly connected to the auricles. It continues upward to the cervical fascia and below is attached to the central tendon of the diaphragm. Thus, the pericardium is a fixed triangular cavity, which tends to prevent any considerable upward movement of the ventricle or apex.

The heart and pericardium are, except for a small space at the left of the sternum, separated from the chest wall by the thin anterior border of the lungs. This, however, may be practically disregarded. The apex is located in the 5th intercostal space, beneath the left nipple.

THE MOVEMENT OF THE HEART AND THE APEX BEAT.

The movements of the heart in the opened chest of a frog or a mammal may be studied by observation or by taking graphic records. It will be observed that the heart beats regularly, the two sides acting together. The wave of contraction starts in the auricle and spreads to the ventricles. After this, the whole heart goes into diastole. The succession of systole and diastole is spoken of as the cardiac cycle, which, in the human heart, averages .8 of a second, .3 being occupied by the systole and .5 by the diastole of the ventricle. (Figure XL.)

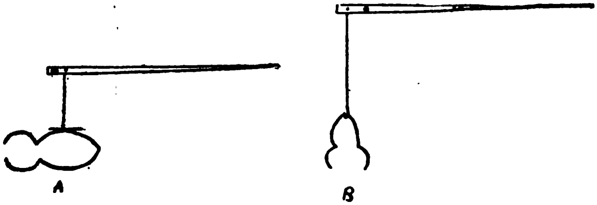

Figure XXXV. Diagrams illustrating methods of obtaining myograms from frog's heart.

Observation of the heart during diastole shows that it tends to flatten by gravity for its walls are softer. This

increases the lateral and longitudinal d
systols, however, the walls harden a
sumes a rounded or conical appe
while the longitudinal and lateral d
decrease, the antero-posterior diamete
perimentally, the shortening of the he
may be demonstrated by causing it t
lever through a string and pin-hook.
B.) It will then be seen that a marked
during the systole of the ventricles.
B.) By placing a small support and a
on a lever (Figure XXXV, A), it ca
the heart does not increase its antero-
throughout systole, but only during th
during the latter part, it remains at a
or gradually flattens due to the fact tha
itself of blood. (Figure XXXVI, A.)
the heart beat are called **cardiograms**
same changes occur in the shape of th
chest. Being held by the pericardium
move up, consequently, the base desc
tudinal diameter is decreased.

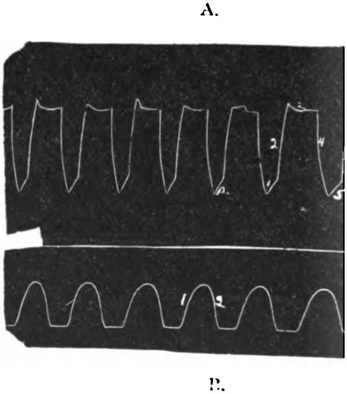

Figure XXXVI. Myograms of Frog's Heart. A
anteroposterior diameter. 1, Systole of auricle;
tricle; 4 and 5, Diastole of ventricle. B, Reco
inal diameter. 1, Systole; 2, Diastole.

If the finger is applied to the 5th in
the left side it will feel an impact o
apex beat. The heart is continually he

but on contracting becomes harder and tends to press upon the intercostal muscles. At the same time it rotates from left to right and so presses the apex more fully against the chest. The base also descends as a result of the straightening of the large vessels. All of these factors help to cause the apex beat.

By means of a tambour system, records of this beat may be taken on a smoked drum. While these records differ in shape, they closely resemble a cardiogram obtained from a frog's heart, showing that during the early part of systole, the heart presses more against the chest wall and later recedes from it.

CHAPTER XXVI.

HEART VALVES AND HEART SOUNDS.

Four valves in the heart need brief description. The tricuspid valve consists of three flaps fastened to the circular muscular ring. The shape of these valves is such that, when they approximate, they form a solid closure of the opening. The valves are rather heavy near their insertion, but become the thickness of paper towards the center. The mitral valve has much the same structure but consists of only two flaps. Projecting into the ventricle are a number of nipple-like processes of the cardiac musculature, the **papillary muscles.** (Figure XLI.) From these arise a number of tendonous cords which pass directly to the valves to be inserted, partly into their margins, and partly into the valves themselves.

During diastole, the valves never come close to the wall of the ventricle but approximate each other more or less. This happens because the blood entering the ventricle from the auricle is in part reflected behind the valves and so keeps them hanging away from the walls. As the ventricle goes into systole, the valves close rapidly by virtue of the increased ventricular pressure. (Figure XL.) This, in fact, would be great enough to cause a bulging of the valves back into the auricles were it not for the fact that the edges approximate vertically and thus cause the pressure to be equal and opposite. Bulging backward is further prevented by the action of the **chordae tendinae,** for the papillary muscles contract with the ventricle, thus tensing the chordae tendinae and making them serve as guy ropes.

The semilunar valves guarding the aortic and pulmonary openings, are quite different in their structure. They consist essentially of three small pockets which come together. The pockets open to the side of the artery and the spaces formed are spoken of as **Sinuses of Valsalva.** The valves never touch the wall of the aorta, because these pockets are always filled with fluid. The semilunar valves open at the beginning of systole, a short interval after the ariculo-ventricular valves have closed. They close immediately after the end of svstole, just before the aricul-ventricular valves open. (Figure XL.) The method of closure may be described somewhat as follows: Blood is always behind the curtains and tends to keep them partly approximated even during systole when the stream is being ejected, for as this ejected blood meets resistence ahead, a part is reflected into the sinuses, expanding the aortic bulb. As soon as systole is at an end, the aortic walls recoil and the valves close with a snap because the pressure in the pockets suddenly exceeds that in the ventricle.

THE HEART SOUNDS.

If we listen over the heart region of the thorax with a stethoscope two heart sounds may be heard. Recently, a third sound has been recognized by Thayer in about 50% of individuals. The first heart sound comes at the time of closure of the auriclo-ventricular valves and is partly due to their closure, but partly, also, to the contraction of the heart muscle. It is loud and distinct at the apex, has a more booming character and is of lower pitch than the second sound. This second heart sound comes at the time of closure of the semilunar valves and is due to their closure alone. It will be seen that the first sound comes at the beginning and the second at the end of the ventricular systole. (Figure XL.) The third heart sound is heard early in diastole and is probably the result of a sudden tension of the mitral valve occasioned by the first inflow of blood to the ventricle. The first sound is heard best at the apex of the heart, i. e., in the 5th intercostal space, the second at the base of the heart, i. e., in the 2nd intercostal space, while the third is rarely heard in the erect position, but most clearly recognized at the apex when the patient is lying in the left lateral position.

CHAPTER XXVII.

THE PULSE AND ITS RELATI
EVENTS OF THE CARDIAC

We have seen that cardiac oscillation
tracings of arterial blood pressure. The
curves is not accurately depicted by the
meter float, as the column of mercury has
This wave of pressure is also transmitt
arterial walls where its presence may be
palpating finger. Synchronous with th
ventricle, the arterial walls grow tense
relax again. We speak of "feeling the
changes in the arterial wall are recorded
magnifies the movement, or by a syste
we can obtain a record of the pulse on
face. Such instruments are called
(Figure XXXVII.) It should be noted
measure blood pressure, but are indicat
pressures.

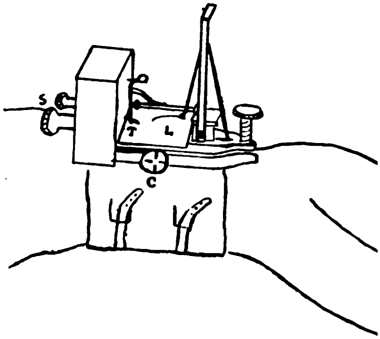

Figure XXXVII. Diagram showing application of Sph
lever recording pulse; T, time marker; S, Screws
for adjusting tension of spring.

The **pulse** may be defined *as a series o*
emanating from the heart and transmitti
walls of the vessels, causing in them a
elongation or both. Each pulse wave,
certain characteristic features. (Figure
It rises rapidly and more gradually desce

ing limb is smooth but the descending limb has several notches and waves. Most prominent and constant among these is the **dicrotic notch** and **wave.** The others are not important and for our purpose may be neglected. It has been shown that the dicrotic notch occurs at the time of closure of the semilunar valves and is supposed to be due to this event. The beginning of the dicrotic notch is then to be regarded as the end of the ventricular systole. (Figure XL.)

From palpation of the pulse, and better by recording a series of pulse waves a number of data regarding the heart and peripheral vessels may be gleaned. 1. The pulse indicates the rate with the heart is beating. The average normal heart contracts about 78 times per minuate, although it is not uncommon to find variations between 60 and 85 which seem to be normal for the individuals in which they occur. The pulse rate is usually slower in men than in women, and becomes faster during exercise. 2. The pulse gives some idea of the regularity of the heart. The normal sequence of the heart is a perfectly regular one but this may become changed in discase. 3. It enables one to discover and estimate any unevenness in the force of the heart's contraction. 4.

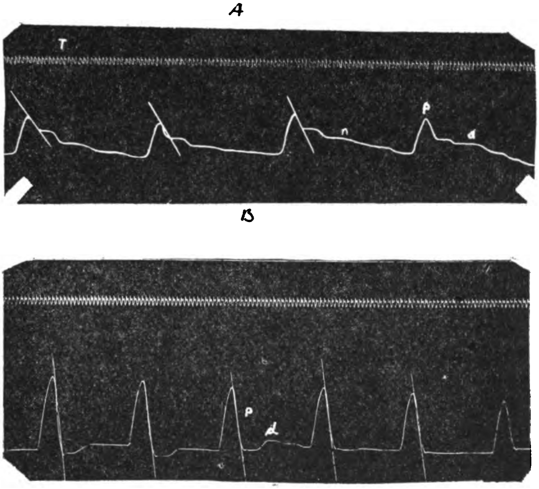

Figure XXXVIII. Pulse Tracings. A. Normal Pulse—p, Primary wave; d, dicrotic wave. Descent gradual, T, time in 1/50 seconds. B. Pulse Tracing showing low peripheral resistance by quick fall of descending limb and a rapid heart beat. (After amyl Nitrite.)

Since the dicrotic notch indicates the ch
to diastole of the ventricle, the pulse a
of the duration of systole and diastole o
mally, the ratio is 3 : 5 but during exer
it may become 3 : 2, indicating that t
the heart is reduced. 5. It permits on
degree of constriction of the periphera
fact that the descending limb of the pul
slopes very gradually is but an expre
that during diastole the arteries slowl
the blood through the arterioles into t
peripheral vessels are dilated the vess
blood on very much more rapidly as sh
rapid fall of the descending limb of su
(Figure XXXVIII, B.)

THE VENOUS PULS

We have hitherto regarded the fl
changes in the larger veins as constant
this is not precisely the case, for disti
both occur in the veins, giving rise t
venous pulses. Under ordinary conditi
are sufficiently contracted to prevent th
the arterial pulse wave to the veins, bu
much dilated, such waves pass throug
into the veins causing a **transmitted ve**
type of pulse, however, is observed on
veins. A second type is seen in the lar
the thorax, particularly the jugular in
each inspiration the veins tend to co
each expiration to fill. This is due to t
of the thorax in inspiration and the ten
th entrance of blood in expiration. H
venous pulse may be designated as the
The term **"venous pulse,"** when unq
other description, is usually not appl
these volume changes, but to a third f
present in the veins of the neck and
origin. When the jugular pulse is rec
bour system similar to that used for reco
pulse we obtain curves which vary mark
subjects as to their general contour bu

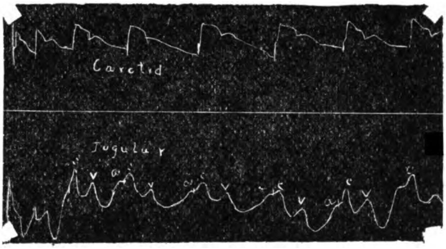

Figure XXXIX. Tracing of Venous Pulse showing three types of waves commonly seen. Upper Tracing, Cartoid Pulse taken as a Guide to Interpretation of Venous Pulse.

distinct waves can be made out. These are called the a-wave, the v-wave, and the c-wave. When the auricle goes into systole, the blood that is prevented from flowing into it accumulates in the large veins and gives rise to a wave, which, since it occurs during auricular systole, has been designated the **a-wave.** When the ventricle has been in systole for a short interval and the auricle in diastole for a corresponding length of time, the latter has gradually become filled to such an extent that a stagnation of the blood takes place in the veins a second time causing the rise of the **v-wave,** likewise named from its occurrence during ventricular systole. As soon as the ventricle goes into diastole, however, it depletes the auricle and the large veins of their blood, causing the fall of the v-wave. Between the a- and the v-wave is another, the **c-wave,** which is synchronous with the rise of the arterial pressure in the carotid and is due to a transmission of the arterial impulse to the veins, i. e., either to an impact of the expanding aorta on the right auricle or an impact of the carotid on the jugular vein. (Figure XL.)

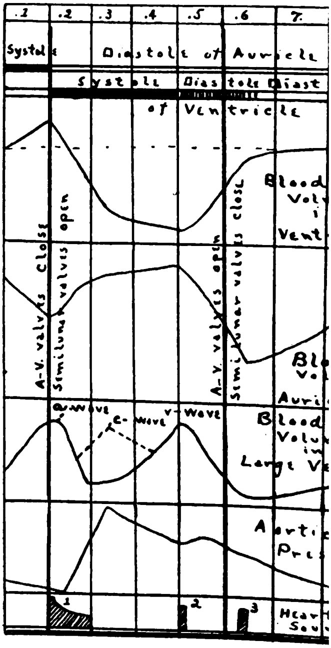

Figure XL. Events of a Cardiac C

CHAPTER XXVIII.

THE CAUSE OF THE HEART BEAT.

Perhaps no subject in physiology has been the subject of such an amount of research and controversy as the views regarding the heart beat. When it was first discovered that the vagus and sympathetic nerves went to the heart, it was at once assumed that the impulses which made the heart contract came to it, as to other muscles, through nerves; and the heart beat was supposed to be caused by some rythmic center, as we now know the respiratory act to be. It was soon demonstrated, however, that the heart might be separated from all nerves, in fact, removed from the body and the beat be made to continue.

With the disclosure of nervous ganglion cells at the mouths of the large veins and auricles and of fibers from these cells passing to the ventricle, the **"nervous theory"** of the heart beat became popular, in accordance with which, it was assumed that *an automatic nervous center was situated within the auricles, from which impulses were spread to auricles and ventricles causing them to contract.* The evidence which seemed for a while to support this theory has, since 1869, been gradually shown to be fallacious, until, at present, the nervous theory has been quite generally abandoned, leaving the so-called **"muscular theory"** to take its place. According to this *in the tubular embryonic heart from which the adult heart evolves, all the muscle fibers hold the properties of irritability, contractility, conductivity and rythmicity. When the heart differentiated into auricles and ventricles, a functional as well as a structural change occurred, so that two types of cardiac muscle developed. The one type, known as ordinary heart muscle and developed to a greater extent in the ventricies, specialized in irritability and contractility and this acquired the mechanical function of pushing the blood along. The other class of cardiac muscle tissue which has been called the* **"Purkinje**

System" *lies in thin irregular strands endocardium and possesses the power o impulse.* (Figure XLI.) *According theory, then, the rythm of the heart is ized form of cardiac muscle tissue, an distributed to the irritable cardiac musci by a contraction.* The order of contr first, then ventricles.

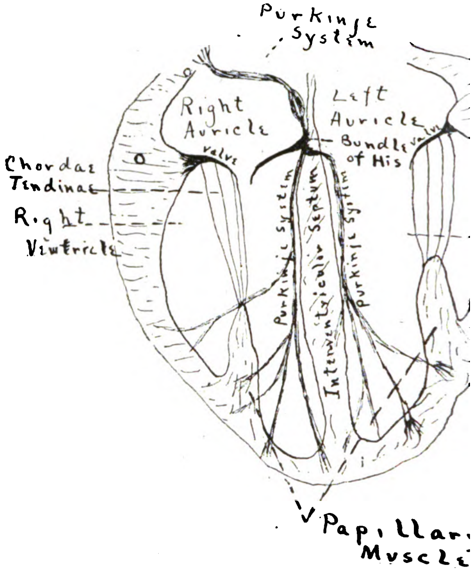

Figure XLI. Diagram showing general Course of Muscle Fibers. Attachment of Chordae Tendir to Papillary Muscles also indicated.

What causes these muscle cells t charge impulses is still a deeper ques began, however, when it was found th heart could be kept beating by allc blood to pass through its vessels, whi an isotonic NaCl solution failed to This showed that more than the mer ence of fluid was necessary. It was al serum unless oxygenated failed to ke ing. Oxygen, then, forms one of the essentials to the beat of the heart. It is not the only one, for an oxygenated salt solution is not efficient in keeping up the beat, but if to this some potassium and calcium are added, the heart will resume its contraction. It is believed that the calcium causes the contraction and the potassium the relaxation of the heart, while oxygen and food supply is necessary to supply energy for the heart.

CHAPTER XXVIV.

THE NERVE SUPPLY OF THE I BLOOD VESSELS.

The heart is capable of maintaining the intervention of nerves. Nerves do beat of the heart but merely regulate it. the heart may be aptly compared to a hc whip and reins. The horse trots at a c to himself, but this movement may be a whip or checked by the reins. So the h by the sympathetic fibers to accelerate the vagus fibers to slow it. For this r nerves are spoken of as the **Accelerator** the **Inhibitory nerves** of the heart.

The vagus fibers come from a grou in the medulla. Leaving the medulla, t pany the carotid artery as the vagus ne to terminate around ganglion cells in t these cells, postganglionic fibers pass t of the auricles, and through them the tricle is regulated. (Fgiure XLII.)

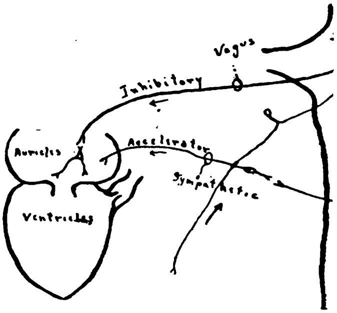

Figure XLII. The Nerve Supply

The accelerator fibers emerge from the spinal cord in the upper thoracic region and pass to the inferior cervical and superior thoracic ganglia, ending around ganglion cells there, whence other fibers pass to the auricles.

Both accelerator and inhibitory nerves are acting continuously but the vagus inhibitory influence is usually more powerful than the sympathetic accelerator influence, so that the heart is actually beating slower than it would be without nerve influence. This varies in different individuals and at different ages, accounting for the fact that the heart slows down from a rate of 140 at birth to 70 or 80 in middle life, to increase again as later years develop. The inhibitory influence of the vagus can be clearly demonstrated experimentally. If the vagi nerves of an anesthetized animal are cut, the heart accelerates. If the peripheral end is then stimulated with an induced current, a complete cessation of the heart and a consequent fall in blood pressure is produced. (Figure XLIII.)

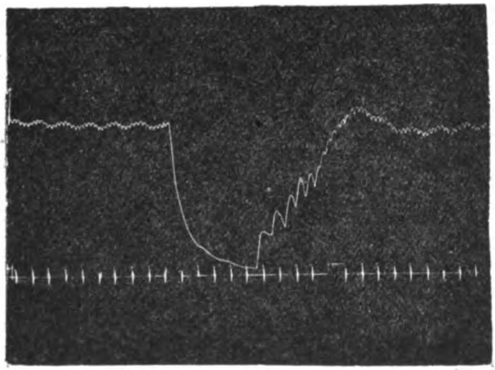

Figure XLIII. Effect of Stimulating the Periphereal End of the Vagus, on the Heart Rate and Blood-pressure.

The vagus center may be stimulated or inhibited. The former causes a decrease in the rate of the heart, the latter an increase. This stimulation may be chemical.

The presence of carbon dioxide and fa
hibit the vagus center while certain dr
it. The center may be influenced b
electrical stimulation of any afferent
decrease in heart rate. Again, the vag
influenced from higher centers as is
change in heart rate during fright and
the center may be stimulated by the a
centers. Thus, whenever the respira
out impulses to induce an inspiration t
and there is also evidence that a disch
motor center can make itself felt in th

THE NERVE SUPPLY OF BLO

The blood vessels are supplied by
fibers causing an inhibition and an
former are the vasodilator and the la
strictor nerves. The vasoconstrictor
are situated in the thoracic region of
and end around ganglion cells, these
the circular muscles of the blood vess
the spinal cord do not constitute the
center but are subsidiary to another
the medulla.

The vasoconstrictor fibers are con
maintain a certain degree of constrictio
arterioles. The vasoconstrictor center i
be influenced mechanically, reflexly, f
in the cerebrum and by the activity of o
These influences may be stimulating
the former case an increased and in the
constriction occurs. A reflex excita
constrictor center may be induced b
central end of the vagus nerve. Whe
impulses are carried by the afferent f
motor and the cardio-inhibitory cen
centers impulses again pass out causin
heart and a constriction of the periph
The latter influence is the more pro
and consequently the blood pressur
XLIV.)

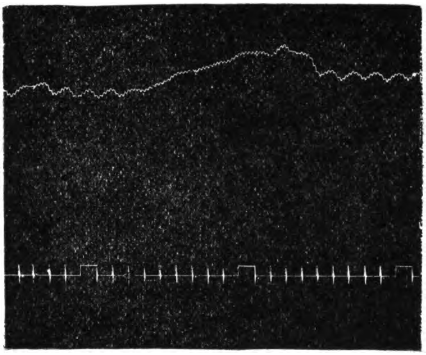

Figure XLIV. Effect of Stimulating the Central End of the Vagus, on the Heart Rate and Blood-pressure.

The action of the vasodilator fibers is antagonistic to that of the vasoconstrictors. When stimulated they dilate the blood vessels. These fibers emerge from the spinal cord at various levels and it is doubtful whether a definite center exists.

SUPPLEMENT.

PRACTICAL EXPERIME

The experiments incorporated in thi
profitably accompany the course outl
in the form of demonstrations befor
number of students. It is not the
author that such demonstrations can
laboratory work. Their introduction
of the conviction that, even with the m
of physiological laboratory teaching,
properly conducted, are not an obsolet
ing. Discussion of this question, exce
dental, pre-medical or college courses
festly out of place here. In such cours
only to maintain an interest in the su
firmly impress the knowledge gained b
ing, but also give the student some ide
and methods by means of which the
have been unearthed. This is of dual
importance of such experiments incu
the part of the student to perform sin
and, consequently, he enters a laborat
enthusiasm for the work. In additio
some insight into the reasons for empl
types of apparatus, the mechanical in
he learns in the laboratory. Seven y
experience with students have impress
the fact that the most difficult prob
teaching is that of keeping the studen
physiological purpose of an experime
lowing the laboratory direction for it

The directions for these practical e
only such descriptions as are required
performance. The results of their per
entered in the spaces left blank for t
entries are to be made in ink at the ti
are performed and, under no conditi
data which the student did not him
made. From time to time these bo
the entries examined, erroneous imp
and a general estimate of the stude
experiments made.

EXERCISE I.

THE REACTIONS OF CARBOHYDRATES.

Reagents Necessary;—1. Lugol's solution—a solution of iodine in potassium iodide and water. The potassium iodide is added to render iodine more soluble. 2. Fehling's solution—a solution of copper sulphate, potassium hydroxide and sodium potassium tartrate.

Experiment 1.—Apply some Lugol's solution to some filter paper (cellulose). Result?

Experiment 2.—To some dry starch apply some Lugol's solution. Result?

Experiment 3.—To some starch add cold water. Shake. Filter and test filtrate with Lugol's solution. Is starch soluble? Proof. Why not soluble?

Experiment 4.—To some starch add boiling water. Filter and test filtrate with Lugol's solution. Is starch dissolved? Why is reaction different than experiment 3?

Experiment 5.—Heat to boiling point about 4cc of Fehling's solution in a test-tube. To this add 1cc of the filtrate from experiment 4. Result?

Experiment 6.—Dissolve some erythrodextrin in cold water. Filter and test filtrate with a drop or two of Lugol's solution. Result? Why called erythrodextrin?

Experiment 7.—Test filtrate of experiment 6 with Fehling's solution as in experiment 5. Result?

Experiment 8.—Dissolve some achroödextrin in cold water. Filter and test filtrate with a drop or two of Lugol's solution. Result? Why called achroödextrin?

Experiment 9.—Dissolve some cane sugar in water. Test with Lugol's solution. Result?

Experiemnt 10.—Test the cane sugar solution with Fehling's solution as in experiment 5. Result?

Experiment 11.—Test a solution of maltose with Lugol's solution. Result?

Experiment 12.—Apply Fehling's test to some maltose solution. Result? What is the precipitate?

Experiment 13.—Dissolve some dextrose in cold water. Test with Fehling's solution. Result?

EXERCISE II.

THE CHEMISTRY OF F

Experiment 1.—(1) To a small amo
a test-tube add water. (2) Shake. (
Result of these three procedures? Is
it form a suspension?

Experiment 2.—To some olive oil
sodium carbonate. Shake. Allow
How do results differ from those of
plain.

Experiment 3.—To some olive oil add a solution of gum acacia. Shake and allow to stand. Compare results with those of experiments 1 and 2. Explain the differences.

Experiment 4.—Shake some fatty acid with water. Is it soluble? Does it foam?

Experiment 5.—To some fatty acid add 10cc of a semi-saturated sodium carbonate solution and heat. Pour a little into a half-test tube of water and shake. Does it foam? What reaction has occurred? Write the formula. What is meant by saponification?

Experiment 6.—To the olive oil and water mixture of experiment 1 add a little soap. Shake and let stand. Result? Explain. What is an emulsion?

Experiment 7.—To some soap solution add some calcium chloride solution. A calcium soap is formed. Write the formula for the reaction. Is it soluble in water?

Experiment 8.—To some sodium hydroxide add some copper sulphate. Result? Now add some glycerine and note effect. Explain. What other substance acts like glycerine when added to sodium hydroxide and copper sulphate?

EXERCISE III.

THE REACTIONS OF PROTEINS.

Experiment 1.—Break an egg and carefully separate the white from the yolk. With scissors cut the membrane contained in the white. To a small quantity of this add some distilled water. Does a clear solution result? Filter. Is the solution perfectly transparent? Compare with a test-tube of water. Egg white contains both albumins and globulins. The globulins are insoluble. The albumins alone pass through a filter in a colloidal solution.

Experiment 2.—To some egg white add a dilute saline solution. Does a clear solution result? Filter. Is this solution clear? Shake. Does the solution foam? What other solutions foam?

Experiment 3.—To a not too dilute solution of egg white apply heat. Result?

Experiment 4.—To a solution of egg white add a few drops of concentrated nitric acid. Result?

Experiment 5.—To 3cc of egg white solution add from 10 to 15cc of alcohol. Result?

Experiment 6.—Acidulate a solution of egg white with acetic acid and add a few drops of potassium ferrocyanide. Result?

Experiment 7.—Render a small am
solution alkaline with KOH and heat.
of a very dilute copper sulphate
What is this reaction called?

Experiment 8.—To a few cc of egg
some Millon's reagent. (Mercuric and
in nitric acid.) Now heat. Result?

Experiment 9.—Add a few drops o
egg white soltuion. Result? Heat.
alkaline with ammonia. Effect?
called?

Experiment 10.—To some shredd
little boiling water. Result? Allow t
consistency? Distinguish between a

Experiment 11.—Test some dilute ge
nitric acid. With Millon's reagent.
compare with those of proteins? Expl

EXERCISE IV.

PHYSIOLOGY OF BLOOD.

Anesthetize a dog or cat with morphine and chloretone given either by stomach tube or injected into the peritoneal cavity. (For details see Edmunds and Cushny, Laboratory Pharmacology.) Insert a canula into the central end of the exposed carotid artery and another into the peripheral end of the external jugular vein. (For details see Lombard's Laboratory work in Physiology.)

Experiment 1.—Withdraw about 15cc of blood from the carotid artery into a small beaker. Observe the changes undergone in ten minutes.

Experiment 2.—a. Draw 2cc of blood into a small test-tube. Note the time (preferably with a stop-watch) before the tube can be inverted without spilling the contents. b. After washing a finger with alcohol, make a blunt stab with one prong of a steel pen and draw a drop of blood. Catch this in a platinum loop and note the time before it is coagulated. Compare the coagulation time of dog's and man's blood.

Experiment 3.—Prick a finger and
blood on the slide. Cover with clean
watch the events taking place during
the low power of a microscope. Descr

Experiment 4.—Draw 50cc of blood i
whip vigorously with a glass rod. A sc
around the rod. What is it? Does the
coagulate? What is the color of the
rod? Place in distilled water and le
What is the color of the mass and of
next day? Filter the colored water.
solution? Is it in solution in the blood

Experiment 5.—Place a drop of blood on a slide and cover with cover-glass. Note the size of the blood corpuscles. Now place a drop of distilled water on one side of the cover-slip and, with a piece of filter paper on the other, draw the water under. Observe and explain the effect on the red cells. What is meant by hemolysis?

Experiment 6.—Repeat experiment 5 using a concentrated sodium chloride solution to draw beneath the

cover slip. Observe and explani th
blood cells.

Experiment 7.—Repeat experime
sodium chloride solution. What effe
on the red blood cells?

Experiment 8.—Draw some blood
artery into a solution of sodium oxal
the blood coagulate? Explain. W
could be employed to bring about a s

Experiment 9.—Draw a large test-tube of blood and allow it to stand 24 hours. The clot will contract and squeeze out a light straw-colored liquid, the serum. What are the differences between blood serum, blood plasma and defibrinated blood?

Experiment 10.—To determine the quantity of hemoglobin contained, use is made of a series of colors of the Talqvist scale. A finger is pricked with a pen and a drop of blood absorbed on a piece of filter paper. The color is compared with the scale and read off in per cent. Results?

Experiment 11.—Into one test-tube draw some blood from the carotid artery and into another some from the jugular vein. Compare the color. Explain the cause of the difference. Allow venous blood to stand in contact with air. The upper layers will change color. Describe and explain.

Experiment 12.—To some defibrinated blood add a dilute solution of sodium nitrite. Note the change in color. To what due?

Experiment 13.—To some defibrinated blood add a solution of H_2S gas. Note the change in color. To what due?

Experiment 14.—Allow some illuminating gas to bubble through a solution of defibrinated blood. Notice the change in color. To what is it due?

Experiment 15—Weber's Test for hemoglobin. 1) To ¼ test-tube of suspected hemoglobin solution add an equal volume of glacial acetic acid and shake thoroughly. 2) Fill the test-tube with ether and extract by gently turning the test-tube up and down. 3) Decant 3 or 4 cc of this ethereal extract into another test tube and 4) add a little powdered guiac, then, drop by drop, 10 to 20 drops of hydrogen peroxide or old oil of turpentine. A blue color developes if hemoglobin is present. Rossel's test employs aloin instead of guiac and a red color is the end reaction.

EXERCISE V.

MUSCULAR CONTRACTION.

Apparatus:—Kill a frog by rapid decapitation and dissect out the gastrocnemious muscle with its tendon (For technic see Lombard's Laboratory Manual) so that its head remains attached to a short piece of femur. To prevent drying suspend it in a moist chamber and attach its tendon to a magnifying level adjusted below the lever (Figure 5.) When the muscle shortens or contracts the lever will rise. This rise is recorded on a kymograph consisting of a drum revolving by clockwork. This drum has previously been covered with a layer of soot by rotating in a flame. The muscle lever brought in contact with this soot rubs it off in its movements.

The irritant used to stimulate the muscle is a single induction shock. The current coming from a battery passes through a key and the primary coil. The lines of electro-motive force around the primary coil set up a current of momentary duration in the secondary coil which slips over the primary coil (Figure 5). This temporary shock is led from the secondary coil to the muscle in the moist chamber by two wires.

Experiment 1.—Stimulate the muscle by closing the key. If the drum is stationary a single arc will be drawn. By moving the drum slowly this line spreads out into a wave, the contour depending on the rate of revolution. Such a record is called a **myogram.** It may be removed from the drum, and permanently preserved by running through a pan of shellac. Make a diagram of the record obtained.

Experiment 2.—Give a muscle a single induction shock and register the contraction on a still drum. Now add a 10 gram weight and move the drum on 5 mm. Then stimulate again and record contraction. Continue this sequence, adding an additional 10 gram weight, moving drum and stimulating the muscle with an induced current until no contraction follows the stimulation. After the curve is shellaced measure the height of each contraction and divide by the magnification of the lever. This gives the actual height that the weight was lifted. The amount of work that was performed may be obtained by multiplying the height of lift by the weight lifted. Tabulate results under following headings.

Height of Contraction divided by mag. of lever.	Weight lifted.	Work.

Experiment 3.—Stimulate a muscle with single induced shocks at the rate of two per second. It will be found that the relaxation gradually becomes incomplete, a condition to which the name contracture is given. Make a diagram of record obtained.

Experiment 4.—Stimulate a muscle with induction shocks repeated 30 to 40 times per second with the aid of an automatic interrupter. The curve obtained rises very high and is maintained longer than a contraction with a single shock. This is called tetanus of a muscle. Make a diagram of the record obtained.

EXERCISE VI.

THE BRAINLESS OR REFLEX FROG.

Experiment 1.—Destroy the brain of a frog by introducing a metal wire into the foramen magnum, stirring the brain and plugging the opening with a pointed match. This process is termed "pithing." Following this operation the frog does not respond to stimulants for some time. This condition is known as "shock" and passes off within a few minutes. The legs are then drawn up and the nose lies down on a plate. The frog does not try to move or jump. If an attempt to extend the leg is made it will be drawn up again. If placed in water, the nose is up on account of gravity but the frog does not try to swim. What functions does this experiment indicate that the cerebrum and cerebellum have?

Experiment 2.—The Effect of Irritants tested on the Reflexes. Suspend a frog from a hook and pinch its toe (mechanical irritant). The leg is flexed. Now apply acetic acid (chemical irritant) to the toes. The leg is drawn up. A similar reaction folows the application of heat or an electric current. What nervous path does the impulse take in going from the toe to the muscle?

Experiment 3.—Hold the right leg and apply a bit of filter paper soaked in acetic acid to the right calf. An effort is at first made to flex the right leg but this being held the left leg is finally flexed and an effort to dislodge the paper is made. This is a case of crossing of a reflex. What kinds of cells did the impulse pass through?

Experiment 4.—a) Dip a piece of filter paper 2 mm. square in acetic acid and place it on the frog's lumbar region. Reflexes pass to both legs and the paper is quickly dislodged. b) Place a piece of paper on the thoracic region. Both the upper and lower limbs flex in the effort to remove it. This shows a spread of reflexes to different levels of the cord. What paths did the impulses take in each case?

Experiment 5.—Dissect out the lumbar plexus and stimulate the peripheral end. The leg extends because the extensor muscles are stronger than the flexors. Why does not the leg extend in response to a normal reflex stimulus? What is a complex reflex act?

Experiment 6.—Inject 1 mg. of strychnine sulphate into the dorsal lymph sac of a frog. Stimulation of the skin soon gives rise to exaggerated and more rapid reflexes. Later the flexion is changed to an extension or spasm. How does strychnine affect the spinal cord?

EXERCISE VII.

THE MOVEMENTS OF THE ALIMENTARY TRACT.

A dog or other animal is anesthetized by a small dose of morphine and by chloretone. Tracheotomy is then performed and the tracheal canula is connected with a rubber tube 2 meters long. The abdomen is now laid open the entire length along the median line. The omentum is cut away so as to bring into view the greater curvature of the stomach, the lower part of the ileum and the ascending and transverse colon. The abdomen is then closed by a transparent sheet of celluloid and the air beneath displaced by a stream of CO_2. Through a stomach tube bread mush acidified with HCl is introduced. Within 10 minutes observe the movements in the alimentary tract. Note the types of waves in the stomach, small intestine and large intestine. What is the rate of contraction?

EXERCISE VIII.

THE ACTION OF SALI

Experiment 1.—Chew a piece of wa quantity of saliva. Note its viscid a sistency. Test with litmus.

Experiment 2.—Add a few drops of sali of starch and water and let it stand fo Test a minute quantity with Lugel's ptyalin acted on boiled starch?

Experiment 3.—To some thin starch p drops of saliva. Test immediately and ev half minute with Lugol's solution. Re changes. Test with Fehling's solution. N What changes has ptyalin induced in *boil*

Experiment 4.—Mix a few drops of saliva with a little water and boil. Now add a small amount of starch paste and test at intervals of ½ minute. Result? What effect has heating on the activity of ptyalin?

Experiment 5.—Acidify some starch paste with .2% HCl and add a few drops of saliva. Test with Lugol's solution as before. Result? Has ptyalin acted in acid medium?

Experiment 6.—Add some saliva to a solution of cane sugar. Test with Fehling's solution every half minute. Result? Does ptyalin act on cane sugar?

EXERCISE IX.

ACTION OF GASTRIC JUICE.

Experiment 1.—To 2cc of a .2% HCl solution add a few drops of dimethyl-amido-azo-benzol. Result?

Experiment 2.—Into 5 separate test-tubes place the following substances and leave in the incubator 24 hours. Tube 1. One-half cubic inch of coagulated egg white and water. Tube 2. A similar cube of egg white and 2cc of pepsin solution. Tube 3. Same as tube 2 plus .2 HCl. Tube 4. Same as tube 3 plus 2cc alcohol. Tube 5. Same as tube 3 but boiled before being placed in the incubator. Note the changes after 24 hours in each tube. Apply the Biuret test without heating. Which tube reacts? What is this a test for?

Experiment 3.—To ½ test tube of milk add a rennet tablet. Result?

Experiment 4.—To ⅓ test-tube of milk add an equal quantity of sodium oxalate and a rennet tablet. How does the result differ from that in experiment 3? Explain.

EXERCISE X.

ACTION OF PANCREATIC JUICE AND BILE.

Experiment 1.—Place a cube of egg white in a test-tube. Add some trypsin and a weak solution of sodium carbonate. In a second tube place a similar cube of coagulated egg-white, trypsin and some .2% HCl. Compare the results after 24 hours incubation.

Experiment 2.—Pour a little bile on a piece of filter paper and touch the edge of the blot with a rod dipped in nitric acid. A play of colors develops, violet, red, blue and green.

EXERCISE XI.

THE URINE.

Experiment 1.—Test the reaction of urine with litmus paper.

Experiment 2.—Determine the s. g. of urine by a urinometer. What is it?

Experiment 3.—Test for chlorides—Acidulate with HNO_3 and add silver nitrate. What is the result? Test its solubility in $NH_4 Cl$.

Experiment 4.—Test for phosphates—(1) Take equal parts of urine and 50% HNO_3. Add ammonium molybdate and boil. What is the result? (2) Add some uranium acetate. What is the resulting precipitate?

Experiment 5.—Test for sulphates—Acidulate some urine with HCl and add barium sulphate. Result?

Experiment 6.—Test for urea.—Add an excess of mercuric nitrate to some urine. The precipitate contains urea.

Experiment 7.—Test for uric acid.—Add
some urine and set aside for 24 hours. Wha
of the precipitate?

Experiment 8.—Test for creatinine.—Ad
acid and a few drops of KOH to some urine
color develops.

Experiment 9.—Test for proteins.—Add
and test with Millon's reagent. What is t

Experiment 10.—Test some urine with F
tion. What is the result?

EXERCISE XII.

THE PHYSICS OF RESPIRATION.

Experiment 1.—Torricelli's Experiment.—Close off a glass tube one meter long by fusing in a flame and fill it with mercury. Insert this in a basin of mercury and the mercury in the tube falls. Measure the height of the column of mercury above the surface of the basin. Its weight equals that of the atmosphere. What is the atmospheric pressure?

Experiment 2.—The manometer and its Uses.—The manometer consists of a v-tube filled with mercury. When both limbs are in connection with the air they are level. Why? If suction or pressure is applied to one of the limbs its level is no longer equal to that of the other limb. Why?

Experiment 3.—Attach a manometer to an enlarging bellows. Fluid rises in the limb showing that the pressure there is less than atmospheric. If the manometer were not attached air would rush in as a result of this difference in pressures. What is meant by negative pressure?

Experiment 4.—Cause of Lung Inflation.—Around the bottom of a bell jar is tied a rubber membrane. In the neck is inserted a two-hole stopper with two glass tubes through it. The one is connected with a water manometer. The other is tied into the trachea of a pair of cat's lungs and the cork inserted. Make a diagram of the apparatus.

Experiment:—Pull down on the rubber diaphragm and the lungs inflate while the fluid in the manometer rises in the limb connected with the bell-jar. When the rubber membrane is allowed to return the lungs collapse. Why? What takes the place of the lining of the rubber membrane in the body?

Experiment 5.—Function of the negative pressure.—Disconnect tube from the water manometer and push up rubber diaphragm. Holding the diaphragm thus, pinch off this tube and connect with the manometer. On releasing, a permanent negative pressure is induced. The lungs remain permanently distended. Pulling down on the diaphragm causes further inflation. What effect has a permanent distension on the quantity of air renewed during each respiration?

Experiment 6.—To obtain a record of changes in the size of the thorax:—Tie a pneumograph about the chest with a slight tension and connect by a rubber tube with a recording tambour (Fig. XLV.). Whenever the thorax

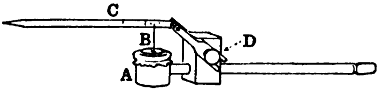

Figure XLV. (From Lombard's Laboratory Work in Physiology) Recording Tambour.

enlarges the spring of the pneumograph is stretched and the air within the rubber chamber is rarified, consequently the lever moves down in inspiration and up in expiration. Draw a diagram of the record obtained.

Experiment 7.—Start the drum and record six or seven normal respirations, then ask the subject to hold his breath as long as possible. Note the length of time. Now tell the subject to take 7 to 10 long and deep breaths and then hold his breath again. The time he will be able to hold it in this case will be much lengthened. Why?

EXERCISE XIII.

THE FACTORS INFLUENCING BLOOD PRESSURE.

The artificial circulation apparatus used is shown in Fig. A number of cautions need to be observed:
1. Always watch the mercury manometer and see that the mercury is not driven over the top. Cease pumping in such an emergency. 2. Never close the clamp representing the constricting arterioles entirely and watch the flow into the bottle representing the auricle. Make sure it never entirely ceases. 3. Be careful not to bend the rods carrying the pointers of the mercury manometers.

Method.

Connect the arterial and venous systems of the artificial circulation apparatus with two mercury manometers, the larger the arterial, the smaller the venous, and open the clamps wide. Now mount a time signal so that its point writes on the same horizontal line with the points of both manometers so that the stylus of the arterial manometer is just ahead of the time signal and the stylus of the venous manometer is just ahead of the arterial. In this way the time signal is used to record the base line as well as the time. (Figure XXIX.)

Experiment 1.—Adjust ths apparatus to normal conditions (1) by limiting the compression of the bottle by sliding a piece of wood under the bar on which the cam operates. (2) By tightening the screw representing the constricting arterioles enough to make the flow into the bottle constant and to cause the venous manometer not to oscillate at all or at least to oscillate very slightly. Pump rythmicaly at the rate of once in two seconds and observe:

1. The ventricle is filled by the suction created during diastole and by the force of gravity. (In the body the contraction of the auricle also contributes.)
2. The fluid pumped out during ventricular systole is (a) partly forced ahead and converted into kinetic energy

or energy of flow as seen by the ent the auricle and (b) partly stored up b the walls of the large arteries, creatin or energy of pressure.

3. The elasticity of the distended ar on the blood and causes the pressure cury manometer during systole.

4. This pressure falls during dia potential or pressure energy is conver flow as shown (a) by the relaxation of and (b) by the continuous character of

5. The pressure in the veins is low is kept up during systole by the contr tricle and during diastole by the relaxa arteries. The resistances introduced be and veins are (a) the capillaries and (b arterioles.

Experiment 2.—(a) Now pump for the regular rate of once in two second at this rate, start the drum at the rat second. Take a record. The venous constant and low. The arterial pressu and, during diastole, gives several oscil inertia of the mercury. Now gradually screw clamp on the tube communiacti cury arterial manometer until these seco disappear. Leave the machine adjuste the following experiments. This me minimize the inertia changes of the me a mean pressure record. (b) Effect of thirty seconds at the rate of once in tw the drum and register five or six pressu increase rate (drum running) to once in record five or six pressure waves. Retur in two seconds and record ten beats. N to once in three seconds and record f drum.

(c) Effect of increasing the output. seconds at the rate of once in two sec drum and record five waves. Now rapi output by lowering the rod on which Record five waves. Stop the drum.

(d) Effect of peripheral resistence. Pump for thirty seconds with the normal output at the rate of once in two seconds. Record five waves and stop the drum. Keep on pumping but loosen the screw representing the peripheral arterioles. Pump thirty seconds then start the drum and record five waves. Stop the drum, keeping on pumping. Now screw down the clamp until a venous flow just occurs. Start the drum immediately and record five waves.

(e) Effect of arterial wall. Pump for thirty seconds and record five or six normal blood pressure waves. Stop the drum. Substitute for the elastic an inelastic stiff-walled rubber tube supplied in basin, leaving the other adjustments as before. Now pump at the rate of once in two seconds for thirty second and again record five or six waves.

Explain in notes (1) Effect of increasing heart rate on arterial and venous pressures and on the size of the arterial oscillations. (2) Effect of increasing the output on same.

EXERCISE XIV.

CHANGES IN THE SHAPE OF THE FROG'S HEART.

Experiment 1.—Pith a frog and pin the animal to a frog board, ventral side up. Remove the sternum with the aid of a pair of scissors. The heart is seen within the pericardium, which is now incised and the heart exposed. Study the sequence of contractions. The systole of the auricle squeezes blood into the ventricles. This is followed by systole of the ventricle. During this event note changes in color, changes in the antero-posterior, lateral and long diameters. State results.

Experiment 2.—To study the change in the length of the heart graphically. A small pin hook attached by a thread to a light straw lever arranged to write on a sooted drum is inserted into the apex of a frog's ventricle (Fig. 36 B.) Since the base is fixed by the aorta, this method records the changes in length of the ventricle during systole and diastole. Make a diagram of the record obtained. Does the heart lengthen or shorten during systole?

Experiment 3.—To study the changes in antero-lateral diameter. Place a small button attached to a light lever on the ventricle and allow it to write on the drum (Figure 36, A). Make a diagram of the curve obtained. What changes does the antero-lateral diameter of the ventricle undergo in systole and diastole? Which of these changes are due to filling and emptying of the ventricle and which are due to the contraction of cardiac muscle?

Experiment 4.—To record the movements of the human heart. Since the apex lies close to the chest wall in the fifth intercostal space and the heart presses more firmly against the wall in systole it is possible to obtain some record of the changes. To do this place a small funnel over this area and connect with a recording tambour Fig. XLV). The record obtained is called a Cardiogram. Make a diagram of it and its interpretation.

EXERCISE XV.

THE CIRCULATION STUDIED

Method.—A small dog, a cat or a ra
The carotid artery is then dissected
the vagus nerve which runs along wi
used, the depressor nerve should als
Apply a clamp to the central end (t
carotid artery and insert a canula.
doubly ligated and divided so as to
(toward the brain) and a peripher
heart).

Apparatus.—The apparatus cons
manometer and a system of tubing

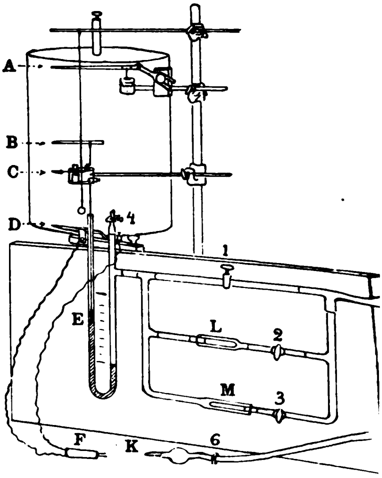

Figure XLVI. (From Lombard's Laboratory
of Apparatus for studying the blood-pressu

sulphate. This is connected with a canula. (For other details of the operation and apparatus consult Lombard's Laboratory Work in Physiology.) In addition, there are used an induction coil and battery so connected as to give induction shocks at the rate of 30 per sec. These are led to the nerves by a pair of platinum electrodes. Some device, either an electric signal in the primary circuit or a short circuiting key writing on the drum, is necessary to indicate the time of stimulation on the record.

Experiment 1.—Remove clamp from artery and the mercury manometer will write the pressure changes on the drum. What kinds of waves are seen? Make a record of the curve obtained and explain.

Experiment 2.—Record a normal blood pressure tracing. Then stimulate the peripheral end of the vagus. Observe that the cardiac waves disappear and the blood pressure falls due to the fact that the heart has stopped. Make a record of the curve obtained. In what other ways could the blood pressure be made to decrease? What is the action of the vagus impulses on the heart? What physiological types of fibers are stimulated?

Experiment 3.—While a blood pressure record is being taken stimulate the central end of the vagus. The blood pressure will rise due to a stimulation of the vasoconstrictor center. Count the number of waves before and during stimulation. Note the effect on the heart rate. How explained? What kinds of fibers were stimulated? (In case the animal used is a rabbit the central end of the depressor may also be stimulated in which case a fall of pressure due to a stimulation of the vasodilator mechanism is obtained.)

Experiment 4.—Perform tracheotomy and rythmically inflate the lungs with a pair of bellows. Now open the chest by cutting through the costal cartilages and tilt the sternum back. Slit the pericardium and expose the heart. Now slip a cardiometer over the ventricle. This instrument consists of a flanged glass globe resembling a small fish globe. Around the flange a rubber membrane is tied and a round opening corresponding in size to the circumference of the base of the heart. Connect its stem communicating with the interior with a recording tambour (Fig. XLV). When the ventricle contracts

it expells the blood from its chamber
time creates a vacuum in the cardior
necting tambour. Thus the lever mov
and up in diastole. Variations in the
show increases of systolic discharge,
the extent of its rise indicate variati
filling. Make a diagram of the instru

Now stimulate the peripheral en
the heart stop in systole or diastol
weak a current that the heart is
effect has slowing on the output?
ing? What relation seems to ex
rate and output? Make a record o

EXERCISE XVI.

THE STUDY OF THE PULSE.

Experiment 1.—The carotid pulse may be graphically recorded by applying a funnel or better still a small metal capsule held by a spring (Fig. XLVII). This is connected by rubber tubing with a recording tambour. As the artery expands it compresses the tissue beneath

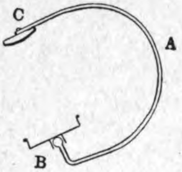

Figure XLVII. (From Lombard's Laboratory Work in
and neck spring used to study the human cartoid

the funnel and causes a positive press
mitted to the recording tambour. As
rises in systole. Obtain a record on a fa
ing drum. What waves are seen? T
due? Where is the period of systole
such a record?

Experiment 2.—The radial pulse
veniently recorded by a sphygmogra
consists essentially of a button actu
of compound lever. The button is
on the artery by an adjustable spri

smoked paper slides through rollers actuated by clockwork and on this the lever writes. (Fig. XXXVII). After adjustment take a normal radial pulse. Notice the shape of the curve and the notches. How does it differ from the carotid pulse?

Experiment 3.—Inhale 3 drops of amyl nitrite, a drug which temporarily dilates the peripheral vessels. Now record the pulse. How does the shape differ from normal? Is the rate changed? Why? Make a record of the curve obtained.

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